Description ofCRYPTOGRAPHERS "HAGELIN" TYPE CX-52

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I. INTRODUCTION


## A. $===$ Foreword

To the users of the Eagelin type C Cryptographers, manufactured since 1936 , such as the $C-36, \ldots, C-48, \ldots, C-446$, and the converter M-209, the exterior and the mechanism of the new CX-52 nachines will seem familiar, even if the indicating disk has been replaced by a stationary alphabet ring and a novable index, placed on the cover for the type wheel assembly. As in the C-machine there is an indicating knob at the left side of the machine, connected to two bypewheels, which is set by hand for each operation.

This knob is mechanically connected to the movable index, by which the letter to be ciphered or deciphered is indicated. By pulling a lever at the right side of the machine, the ciphering or deciphering of each letter is effected, as a slidebar drum, controlled by six keywheels, is then revolved for one complete turn, during which the alphabetwheel unit is displaced a number of steps. The primary letter is printed immediately before the displacement begins, the secondary letter is printed after its completion, and the tape, on which the letters are printed, is then advanced to receive the following imprints.

The description aims to give a clear explanation of the functions and the cryptographical properties of the machines. It has been found pertinent to make some references to, and comparisons with the earlier types. When making such references, type C-446 will be cited; a description of this machine will on request be supplied to those who are not familiar with it.

Some expressions in the description may sound unfamiliar or even incorrect to the reader. No internationally approved vocabulary, pertaining to ciphering machines has however been established, and the correct usage of some cryptological terms is still disputed. The purpose of the appended list of definitions is therefore only to help the reader to understand the meaning of certain special expressions in the following description.

## B. General remarks


The new machines are the result of the experience gathered during more than 25 years of manufacture of ciphering machines. The application of new principles offers the users new and valuable possibilities. Due to the completely new design, operation and servicing will be siaplified.

The new machines have the following characteristics in common with the machine C-446:

1. Small overall dimensions: $198 \times 138 \times 105 \mathrm{~m}$

> (ab. $73 / 4 \times 53 / 8 \times 41 / 8 "$ ) including protective cover.
and low weight : 3 kgs (ab. 6,6 lbs.)
2. The same machine is used for both ciphering and deciphering.
3. The clear(plain) text and the enciphered text are rendered in printed form on separate tapes. The two tapes are however in this machine cut from one single strip by a rotary cutter, which is incorporated in the paper feed mechanisa. The new paper roll has the same width as the standard telegraph perforated tape, $17.3 \mathrm{~mm}(11 / 16 \mathrm{l})$, and is placed conveniently accessible in the baseplate. When enciphering, both texts are automatically divided into groups of five letters, and the letter in the clear text, which indicates the space between words (such as the $x$, w or other, depending on the language used), is also printed; when deciphering the cipher text is printed in a continuous sequence, while the clear text is rendered with the proper spacing between words. This arrangement has been chosen not only because it simplifies the construction of the printing unit and brings the convenience of a single paper roll, but also because the comparison and control of the texts will in this way be aade easy: the corresponding letters of the two texts will always be found exactly one above the other, when the tapes are laid alongside each other.
4. The operating speed is satisfactory, as from 30 to 60 letters per minute can be rendered, depending on the skill of the operator.
C. Definitions
$===============$
Arbitrary alphabets.
When arbitrary alphabets arc used, the sequence of the letters of both the primary and the secondary alphebet is chosen at random The use of arbitrary alphabets demands two alphabetwheel units, one for the ciphering and the other for the deciphering operation.

Inverse alphabets.
These can have the noral (alphabetic; sequence of the letters or any desired sequence, only the sequence of the letters of the secondary alphabet must run in opposite direction to the sequence of the primary alphabet. With inverse alphabets the same alphabetwheel is used both for enciphering and for deciphering.

Enciphering and deciphering.
These operations are, seen as machine functions, identical. Then such operations of the machine are described, they will always be colled ciphering, in order to avoid the repetition of the expression "enciphering or deciphering", unless deciphering is specifically doscribed.

## Keys

The machine contains a number of variables, which have to be set according to instructions, prepared by those responsible for the cipher service in question. Dach setting of a variable corresponds to a specific key for the element in question. Wetting all the variable elements (according to instructions) corresponds to the "keying" of the machine.

The purpose for the specific keys is

- on one hand to have the machine produce a cipher of a high quality,
- on the other, to perait the correspondence between two or nore users. A correspondence will evidently be possible only if all the variable eleaents are set identically,
- and finolly to set those elements, whose positions will change during operction of the aachines (the keywheel units and the typewheel assembly), in their identical starting positions.

We shall call the firstnamed settings: basic keys, and the keys for the starting positions: initial keys.

Basic keys.
These comprise the following elements
a) The bar drum:

1)     - types of bars used
2)     - the arrongenent of the lugs on the bars

3, - in cortain cases, the sequence, in which the bars are placed.
b) The key whoèls:

1)     - the choice of keywheels to be used
2)     - the sequence, in which they are placed in the machine
3)     - the arrangement of the pins in the pin disks
c) The typewheel assembly:

In case rearrangeable letters and types are used, their sequence or when using interchangeable alphabet rings their choice.

Initial keys:
These comprise the following elements:
d) The position of the keywheels, defined by the inciex letters on their crowns, relative to the index line on the machine cover.
e) The relative position between the two typewheels of the alpha-bet-wheel unit, defined by the place of a chosen index letter on the indicating disk.

Displacement and advancement.
The ciphering operation consists in causing the alphabet unit to change its position, after having set it to indicate the prinary letter. As the alphabetwheel normally carries 26 letters on each ring, it enn take 26 different positions. Tho ciange in position, which is caused by the slidebar drum which revolves one turn for each operation, and which acts as a gear sector which meshes with the alphabetwheel gearing, is called displaceuent.

The number of steps (each step is $1 / 26$ th of a revolution) is called displocenent steps. The series of displacenent steps which follow one after another, for the ciphering of a message, is called displacement series, or substitution series. As the displacement series is defined by the arrangement of the keywheel and their movement, it can in sone contexts also be called key series.

The keywheels are subjected to a similar displacement as the alphabetwheel unit, although we may use the advancement in such cases when we want to distinguish between the novenent of the alphabetwheel unit and the keywheels.

The word displacement is also used in connection with the slidebars as a better expression has unfortunately not been found. The slidebars, which are contained in slots in disks, of which the drum is made up, can take two positions, by being slid from a right end position to a left end position, for a distance of about $21 / 2$ rans $(0,1 ")$. We call the right end position the undisplaced and the left end position the displaced position.

## Indication

When a nessage is to be ciphered, the noveable index is brought to register with the letters in the text - they are indicated-after which the operating lever is pulled and the ciphering operation is effected.

Prinary and secondery
These terms are used to denote that when a nessage is to be enciphered or deciphered, the text in hand is the prinary text, and it is printed by the prinary typewheel; the result of the operation is the secondary text, printed by the secondary typewheel. Thus, when enciphering, the original clear text is the primary text, and the resulting cipher is the secondery text; when deciphering, the cipher is the primary text, and the reconstituted clear text is the secondary text. The primary text consists of primary letters, the secondary of secondary letters.

## II. GENERAL DESCRIPTION



## A. Principal units


The machines type CX-52 are assembled from the following six main units:

1 - Baseplate
2 - Left bearing Plate
3 - Slidebar Drua
4 - Right bearing Plate
5 - Keywhcel Units
6 - Alphabetwheel Unit
In order to facilitate the identification of the different parts, the first digit in the number given to a part, will be that of the main unit:

Parts, belonging to the Baseplate1
the Left Bearing Plate ..... 2
the Slidebar Drua ........... 3
the Right Bearing Plate ..... 4
the Keywheel Units ... ...... 5
the Alphabetwheel Unit ...... 6
The units are listed in the sequence they are assenbled into a complete machine, with the Baseplate as starting point and foundation.

We refer to the list of illustrations which is treated in "B". Not all parts enumerated there, may be visible on these illustrations: they will be shown in a separate complete parts list, L 013.

List of nentioned parts.
Numbers in [ ] brackets are group numbers and not shown while their component parts are given on the pictures
[1]
Baseplate

Under side:

101
102
103
104
11
111
1111
112
12
121
122
123
124
13
131

14

15
151
16
17
[18]
181
182
1821
183
184
185
paper roll guard 3
tape transfer slot 3
keywheel grooves 4
tension regulator 3
botton cover plate
bottom cover plate pin notch none
rubber feet 1
10ck
lock arn for outer cover (15)
shown on the pictures:

1
botton cover plate pin none
lock arn for machine cover (47) 2,4
nain key (with two notches) 2
operator's key (with one notch) none
paper roll 3
paper tape 3,5

## Upper side:

release latch for bottom cover plate (11)
outer cover
locking hook for (121)
keywheel retaining bar
4,5
1,2
2
recoil spring
retractor unit
retractor bar
right arm
can follower
5
,3,11
8
left arra
journal bracket
flat spring.
8 to 11
none
8
none

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## Left side:

pictures:

## [21]

211
212
[213]
2131
2132
[214]
2141
2142
215
216
217
218
219
[22]
221
222
223
2231
224
225
226
2261
227
228
[23]
231
232
2321
233
234
,


Printing unit
axle
none
C-D knob
2,4
primary printing lever printing hamer rear end of lever
secondary printing lever printing hamer rear end of lever
spacing lever
grouping control lever
spring of primary printing lever
spring of secondary printing lever 4
paper guard
4

Paper feed device:
feed roller axle
none
paper feed knob
1,4
feed roller
4
cutting disk 4
ratchet wheel 4
friction roller bearing axle 4
friction roller 4
cutting disk 4
friction roller cradle $\&$
ratchet lever
Can unit:
drive extension 13
prinary printing can 13
F-V car 13
secondary printing earn none
paper feed can none

| 5-letter groupor | pictures |
| :---: | :---: |
| letter grouper axle | none |
| counter drivo | 4 |
| ratchet wheel | 4 |
| control disk | 4 |
| F-V device | 4 |
| control knob | 1,13 |
| control shaft | 13 |
| lever unit |  |
| slide lever | 13,14 |
| lever extension | 13 |
| fixed lever | 13 |
| spring | 13,14 |
| retractor fork | 4,13,14 |
| axle | 13,14 |
| side cover | 2 |
| alphabet-wheel cover | 2 |
| release knob | 2 |
| knob "C" [for (273)] | 1 |
| counter | 1 |
| reset knob | 1 |
| primary ink roller | 2,4 |
| secondary ink roller | 2,4 |
| primary locking pawl | 2 |
| secondary locking pawl | 2 |
| knob "R" [for (274)] | 1 |
| right side: |  |
| slidebar reset disk | none |
| journal plate | 4 |
| slidebar drum stop lever | none |
| interwediate gear wheel | 5 |

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371 \& 376
372 to 375
38
381 to 387
388
39
4
41
411
42
43
4.5

46

461
462
463
47
473
474
475

Slidebar drum
drum shaft
left end disk
stop control can
notch
slidebar retaining ring
slot
right end disk
retractor bar can (for (181))
guidearre locking bar cae notch
driving gear
ratchet notch
bar supporting disks
supporting disks none
supporting disks
slidebar
slidebars driving teeth
notched right ends of bars
movable lug
Right bearing plate
operating levex
retractable handle
gear segnent
spring
locking lever
guide arn locking bar
left arm
right arm
bor extension 8
inner cover
disk slots 5
index line
locking pin 2
opening for handle (411)

2 1
4,12
8,9
5
none
none
5
5
5
8 to 11
8,10
8
8
none

5
$2,5,3,12$
12
none
2,5,12
5
1,5
1,5
none
2,5
8,10
2,8,
10 to 12
8
8


5

51
511
5111
5112
512
53
531
54
541
5411
5412
542
5421
544
55
56
561
57
571
572
573
58
59

61
62
63
631
64
641

Keywheel unit
pin disk
disk pins
active pin
inactive pin
disk positioning slot
driving and locking gear
positioning pin
guidearm assembly
feeler arm
feeler extension rear extension
guide arm
guide surface
spring
locking pawl
intermediate gear
stud
bearing plate
hullow bearing
spring-pin
noteh
spring
positioning shaft

5,7
2,4,5,12
5, 7, 8
5
7,8,9
7,8,9
7
5,7
7
5,10
7,9
7,8,9,11
7,8
7,9 to 12
7,8,12
7,8,11
5,7,12
7,12
none

7
7
5,7
7,8,9
4,5

Alphabet wheel unit
Note: there are: a) fixed alphabets
b) rearrangeable alphabets
only b) is shown
operating knob
1,5
gear wheel
5,13
primary thypewheel
2,5,13
type ring
5
secondary typewheel
2,5,13
spacing pin
driving cred locking gearwheel 2,5,13
hollow bearing
positioning notch 5 nene
spring noze

Subassembly, mounted in cover (2601)
indicating disk 1
indicating ring 5
rearrangeable letters
5
691
6911
692
morable index 1 red index 1
gear wheel 2

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B. Illustrations

Picture 1 is a general view of the machine, with outer cover 15 opened.

There can be seen on the left side:

- the control knob
- the reset knob (2611)
- the paper feed knob (222)
- the operating knob (61)
- the indicating disk (69)
- the knobs "0" and "R"

Throughthe six slots (473) in the inner cover (47), across which the white indexline (474) is drawn, the six pin disks (51) are seen. At the extreme right the operating lever (41) is visible. Picture 2 is similar to picture 1), only the covers (2601) and (47) are opened, and we can now also see:

- the type wheels (63) and (64)
- the gear wheel (66)
- the key wheels (5)
- the bar (46)
- part of the drum with a number of bars (38), carrying lugs (39)
- the gear wheel (692)
- the knob (26011)
- the ink roller (271) and (272)
- the locking pawls (273) and (274)
- the main key (123)
- the spring (43)
- the lock arms (121) and (122)

Picture 3 is a bottom view, with the bottom cover (11) removed. It shows:

- the tension rogulator (104)
- the paper roll (13)
- the guard for same (101)
- the tape transfer slot (102)
- the tênsion regulator (104)
- the lock (12)

Picture 4 shows the machine with the following parts removed: The covers (26) (15) (2601) (47; the alphabetwheel unit (6), the keywheel units (5).
This allows us to see, to the left of the plate (2),

- the printing unit (21) with paper guard (219)
- the paper feed device (22)
- the letter grouper (24)
- the F-V device (25)

Further to the right we see

- the keywheel unit grooves (103), and
- the sixth keywheel unit (5)

The shaft (59) has been partially pulled out.
Picture 5 shows the machine from the front, with all covers opened, and with the following parts removed: the five keywheel units (5) I to IV and VI, and the alphabetwheel unit (6). In the machine we see:

- the paper tape (131) as it leaves the feed mechanism
- the keywheel unit (5) V
- the drum with end disks $(32,33)$
- the supporting disks (372 to 375)
- the retaining ring (323)
- the slidebars (38) with lugs (39)
- the operating lever (41) with retractable handle (411)
- the keywheel positioning shaft (59), partly withdrawn.

In the right side plate (4), the hole (48) is seen, in which the handle (411) lodges, when the machine is closed up. One of the bars (38) is shown partly removed.

The slot in the retaining ring (323), through which the left end of the bar has passed, is also visible.

In front of the machine, we see:
a) - alnhąbetwheel unit (6) with operating knob (61)

- the indicating disk (69)
- the primery and sozondary typewheel $(63,64)$
- the cwi-ing gear wheel (66)
b) Three keywheel units (5) with keywheel plate (57)
- the locking pawl (55)
- the guide arm (54)
- the driving gear (53)
- the pin disk (51)
- the pins (511)

The notch (573) in the bearing plate engages the bar (16) when the keywheel units are in place.

Picture 6 shows the slidebars (38) which are normally supplied for the machine type CX-52, shown in nondisplaced positions. The seven rows of double lines make it easy to recognize the different types of teeth used on the slidebars. The left of each set of double lines shows the path of the intermediate gear (56), and the right set the path of the locking pawl (55) in relation to the teeth (381 to (387) of the slidebars (38).
The CX-bars must have 7 sets of teeth.
Picture 7 shows the keywheel unit (5) in detail.
Picture 8-11 show the basic operation of the guidearm unit cycle (see page 27-29)

Picture 12 gives a summary of the action of the slidebars with the different driving teeth types (see page 29-30)

Picture 13 and 14 show the two basic settings of the F-V device viz; the position $F$ in picture 13 and the position $V$ in picture 14 (see page 21).
C. Detailed explanation.
$===========================$

1 - The baseplate (Picture 1 to 5)

The baseplate (1) has the shape of an inverted rectangular box. The hollow space is used to house the paper roll (13), which becomes accessible when the bottom cover plate (11) is removed. The cover plate is locked in place with the latch (14), which engages with a notch (1111) in the bottom plate pin (111), and can be released only when the outer protecting cover (15) of the machine is opened. Four rubber feet (112) in the plate (11) assure a firm stand for the machine, when in use. The slot (102) permits the transfer of the paper tape from the roll to the printer compartment of the machine.

A special lock (12) with two lock arms (121, 122) serves to lock the outer cover (15) and the inner cover (47). When the operator's key (124) is used, this will unlock only the outer cover (15) which will allow to use the machine.

With the main key (123) both covers will be unlocked, and the ciphering mechanism will also become accessible for the setting or rearrangement of the keying elements.

On the upper surface of the baseplate (1) there are six shallow. grooves, (103) with a bar (16) riveted across them, which serves for the positioning of the keywheel units (5). The baseplate is further drilled and tapped for screws, with which the following parts are fastened:

- the outer cover (15)
- the bearing plates (2) and (4)
- the latch (14)
- the recoil spring (17)
- the retractor unit (18)

The retractor unit (18) is used for the control of the keywheel-guidearm-units. It consists of the retractor bor (181) which is cradled in the journal bracket (184). The cam follower (1821) of the flat spring (185) presses the cam follower (1821) of the right arm. (182) against the cam (34) of the slidebar drum unit (3).

2 - Left Bearing Plate (Pictures 2,4,5)

This part is heavily channelled, and contains several mechanism:
a) - the printing unit (21) with paper guard (219)

- the paper feed device (22)
- the cam unit (23)
- the 5-letter grouper (24)
- the F-V device (25)

The side cover (26) encloses these parts.
Inside the side cover (26) the three-digit counter (261) is rounted; it can be read through an aperture in the cover. The counter checks automatically with the counter drive (242) when the cover (26) is put in place; the knob (2611) serves to reset the counter (261) to zero.
b) on the right face are mounted:

- the slidebar reset disk (28)
- the journal plate (29), with the bearing for the shaft (59)
on the journal plate (29) are mounted:
- the slidebar drum stop lever (291)
- the intermediate gear wheel (292)
- the locking pawl (274)

A cover (2601) is hinged between the side cover (26) and the journal plate (29); it protects the alphabetwheel unit (6) and holds the indicating disk (69).

21 - The printing mechanisu (picture 4.)
It consists (from loft to right) of:

- the C-D knob (212)
- the printing levers (213 a 214) with the spacing lever (215) and the grouping control lever (216), which are mounted on the axle (211).

The forward upper ends of the printing levers carry rubber tipped hawer heads (2131, 2141); the rear ends $(2132,2142)$ of these levers press against the cams $(232,233$ ) of the cam unit (23), which is mounted on the left end of the drum shaft (31).

The two coil springs $(217,218)$ provide the striking force for the printing hammers.

The cam (232) is notched to allow the printing hammer (2131) to strike against the primary typewheel (63) at the beginning of the operating cycle.

The cam (233) is notched so that the hammer (2141) will strike at the end of the cycle against the secondary typewheel (64).

The paper tape (131) is inserted from the under side of the baseplate (1) through the tension regulator (104), the transfer slot (102), the paper guard (219), and between the feed roller (223) and the friction roller (226).

22 - The paper feed roller (Picture 4)
The roller (223) is mounted on the axle (221). At the left end of the roller is a knob (222) by which it can be turned by hand; at its right end is a ratchet wheel (224).
The friction roller (226) is mounted in the cradle (227), which is pivoted on the axle (225) and presses against the roller (223) by tension from the springs $(217,218)$, whose upper ends are fastened to the cradle.

The feed roller and the friction roller are fitted with cutting disks (2231, 2261), which cut the tape into two strips when the tape is advanced between the two rollers.

23 - The cam unit
The cam (232) has an additional curve (2321) on its left side, for the operation of the F-V device (25).

To the right of the cam (233) there is a cam (234) for the operation of the paper feed ratchet lever (228), which engages the ratchet wheel (224), and causes the feed roller (223) to turn one step for each operation.

When enciphering however, the 5-letter grouper (24) will permit the ratchet lever (228) to make a longer feed movement for each fifth operation, so that there will be an extra space between each 5-letter group.

The notched drive extension (231) of the cam unit (23) serves as a coupling when the machine is mounted on the B-52 device, for electric drive.

It will be seen that all movements, for the printing ond for the advancement of the paper tape are controlled by the cam unit (23). These movements have been timed in such a way that the primary letter will be printed on the left part of the tape, before the displacement of the alphabet wheel unit begins, and the secondary letter will be printed on the right part of the tape after this operation. The tape is advanced (and cut at the same time) immediately before the primary letter is printed.

## 24 - The 5-letter grouper

This device is mounted on the axle (241) and carries a control disk (244), (with two diametrically placed notches) and a ten-teeth ratchet wheel (243).

At the extreme right of the cam unit (23) is on excentric cam (234) on which the ratch $t$ drive lever (228) is placed: this advances the control disk (244) one tenth of a revolution for each operation. The control notches will allow a double-space feed for every fifth operation, if the C-D knob is in C-position (i.e. (En)Ciphering). When the $C-D$ switch is in D-position (Deciphering), the control disk will become inőperative.
The coupling between the 5 -letter grouper (24) and the counter (261) can only take place in one position, which has been chosen so that the 5-1etter space will coincide with a 0 or 5 on the unit digit of the counter (i.e. 110, 235, etc.)

It should be mentioned here that the C-D knob has also another function:

1.     - When in D-position, it will place the spacing lever (215) where it will contoct the spacing pin (641) of the secondary typewheel (64), and prevent the printing of the letter which has been designated to represent the space between words, when this is in the printing position.
2.     - In C-position, the spacing lever (215)will be inoperative.

The function of the C-D knob will therefore be, when in C-position, to effect an extra space between each group of five letters printed, and, when in $D$-position, to prevent the printing - by the hamer (2141) - of the letter which denotes "space" between words.

25 - P-V Device (Pictures 13 \& 14)
"F-V" stands for "Fixed-Variable".
This device consists of the axle (256) which is journalled in two journal holes, in the front and in the rear extension of the bearing plate (2).

At the rear end of the shaft, is the lever unit (2531, 2532), and at the front end the retracter fork (255).

The lever (2532) is fixed on the shaft, while the lever (2531) can slide on it. It is kept pressed towards the rear by the action of the spring (254) which presses on the lever extension (25311).

The operating knob (251) is mounted on the axle (252), and depending on which of its two positions it is placed, tie lever (2531) will be placed either to follow the curve (2321) on the cam (232) (position "V", picture 14), or it will come free of this curve (position " $\mathrm{F}^{\prime \prime}$, picture 13).

In the position "V", the cam (2321) will cause the retractor fork (255) to pull the primary unit $(61,62,63)$ away from the secondary unit ( 64,06 ), immediately after the printing of the primary letter, and will restore the connection at the end of the operation. In this way, the priwary unit will rest stationary, when the secondary unit is displaced, and the relative position of the two units will be changed for each operation.

In the position "F", the two units will turn together during the displaceaent operation.

28 - The reset disk
Its function is to return those slidebars (38), which have been displaced to the left during an operation, to their initial right position.

291 - The stop and release lever

This lever provides a positive stop for the slidebar drum (3), when this, on being operated, has completed a revolution. This stop is released when the alphabetwheel (6) is set to indicate a new letter.
292. - The intermediate gear and the locking pawl

These serve to transmit and control the displacement movement, which is effected by the slidebars (38), on the alphabetwheel (6).

3 - The slidebar drum.

The drum is dowelled on to the shaft (31), the right end of which is carried in the right bearing plate (4); its left end protrudes through a bearing in the left bearing plate (2), where it carries the cam unit (23).

The drum proper consists of two slotted end disks (32 and 33) and six intermediate supporting disks (371 to 376) all with thirtytwo slots each over approximately $3 / 4$ of their circumference. The end disk(32) is filled with the cam (321) the notch (322) and the retaining ring (323)

The numbers "1" to "32" on the outer circumference of the right disk (33) serve to identify the slidebars. An endess coil spring is placed inside the disk (33), over the notched ends (388) of the slidebers, and serves to hold them in a given position (displaced or indisplaced) during the moment when the slidebar in question passes through its operative sector.

The slotted disk (33) is integral with the retractor bar cam (34), and the guidearm locking cam (35). A tooth (351) is machined in the right face of the cam (35).

The driving gear (36), which is free to turn and to slide on the shaft (31), has a ratchet notch (361), to correspond with the tooth (351).

The six supporting disks ( 371 to 376 ) are identical; their unslotted portions are shaped to function as locking pawl control cams for the keywheels units. The supporting disks are placed at equal distances between the end disks $(32,33)$. In the slots, the thirtytwo slidebars (38) are lodged.

38 - The slide bars (picture 6 \& 12)

The slidebars carry seven driving teeth ( 381 to 387 ), which are integral with the slidebars; they can also be provided with one or several lugs (39), where required, which are reparrangeable by hand. They are kept in place in the drum slots by the numbered ring of the right disk (33), and by the ring (323). The ring (323) has an opening (3231), and the ring can be turned, so that the opening can match with any one of the slidebars and allows this to be removed or inserted through the opening. The ring is normally kept in the position where a small spring latch enters into the opening (3231) and locks the ring.

The bars can take two positions:

- the right position, "nondisplaced", in which all bars are.at the starting poins of each operation
- the left position, "displaced".

The movement amounts to about $21 / 2 \mathrm{rm}$ (0.1").
The bars are provided with lugs (39) by which the guidearm of the keywheel units (5) can move the bars from the right to the left position. The left ends of the slidebars, abut against the reset disk (28).

The bars are kept in their right position by the reset disk (28) when the drum is in its initial position. When the drum starts to revolve for an operation, the bars become free, one after another, to be pushed over to the left position. This movement is efiected by the oblique surface (5421) of the gui fearms (542) and takes place only when a guidearm (542) is in an active position (olose to the drum), and a lug (39) on the bar in question is placed in the path of the active guidearm.

In the same sector the driving teeth (381) to (387) act to engage with the pinion (53), or to lock the locking pawl (55) of the corresponding keywheel unit. Then the bar has passed the active sector, it will be pushed back in to the right hand position - if displaced - by the reset disk (28).

There are five different kinds of driving teeth: see picture 12).
Type A: will displace a keywheel, when the slidebar is in its displaced left position, but will remain inoperative in its undisplaced right position.

Type B: will be active in the right but inoperative in the left position.

Type C: will be active in both positions
Type 0: will be inoperative in both positions
Type K: is normally in the displaced position. (This tooth is user only for the displacement of the alphabet wheel unit).

There are seven teeth on each slidebar: The ifirst for the alphabetwheel unit, and the next six for the keywheels.

4 - The right bearing plate (pictures $5 \& 8$ )

This carries the operating lever (41) with the gear segment (42). The retractable handle (411) can be pushed into an opening (48) in the bearing plate, holding the lever in its forward horizontal position, to permit the closing of the cover (14) when the machine is not in use. When the handle (411) is pulled out, the lever will snap up into its vertical position. The gear segment (42) meshes with the pinion (36) on the slidebar drum shaft (31). A spring keeps the pinion (36) under a slight pressure against the cam (35), so that it will engage the notch (351), when the lever is pulled for-ward-downward through an are of about $90^{\circ}$, and the drum will be caused to turn one full revolution. A spring (43) will draw the lever and the segment unit back again to be ready for the next operation, when released. The locking lever (45) is pivoted on a

3027
pin in the bearing plate. Its forward end is drawn downwards by a spring against the cam (35) on the slidebar drum. The locking lever has two functions:
a) it acts as a reverse check, so that when the drum has completed a revolution at the end of an operation, it cannot be turned backwards.
b) it also operates the guideara locking bar (46).

46 - The guidearm locking bar (picture 8)

This bar is carried by two arms (461) \& (462), which are pivoted in pins in the right bearing plate (4) and journal plate (29) An extension (463), to the right of the guidearm locking bar, engages with the lever ( 45 ), and will take two positions, one upper and one lower, depending on against which part of the cam (34) the lever is pressing.

The portion of the locking arm which lies between the arms (461) \& (462), has an inverted U-section, which will in its lower position bear down on those of the guidearms which are close to the drum, and at the same time keep the other guidearms away from the drum, during the displaccment period of an operation.

47 - The inner cover (picture 2)

The cover (47) is hinged at the back, at the left on a pin in the left bearing plate (2), and at the right on a combined screw and pin. Loosening the screw permits the renoval of the cover. The lock arm (122; engages the pin (475), when the inner cover is locked. The six slots (473) in the cover (47), across which a white index line (474) is dxawn, permits the setting of the keywheels by hand.

5 - The keywheel units (picture 5 a 7)

These units consist each of the pin disk (51) with the pins (511), the driving gear (53), the guide-arm assembly (54), the locking pawl (55), and the intormediate gear (56).

All these parts are placed on the bearing plate (57), the keywheel unit on a hollow bearing (571), the check pawl on the pin (572) and the intermediate gear (56) on the stud (561)

The intermediate gear (56) meshes with the gear (53); the check pawl (55) is held against the gear (53), and the guidearm (54) to the right side of the key disk (51) against the pins, by the springs (58).

The construction of the guidearm assembly (54) will be described in the proper context: it will only be added here, that, when the keywheel unit is in its place in the machine, the arm extension (5412) which projects rearwards, will come immediately below the retractor bar (181): when this bar moves downwards, under action from the can (34), the upper end of the guidearn assembly (54) will be retracted from contact with the pins, and move over close to the circumfexence of the slidebar drum (3).

54 - Guide-arm assembly (pictures 5 \& 7 to 12)

The reason for the relatively complicated construction of the unit (54) is the following: The displacexent of the alphabetwheel unit and the advancement of the keywhecls take place simultaneously; therefore, during this operation the guidearm unit positions must not change, and at the same time the guideara must not interfere with the advancement of the keywheels. The position of the guidearm, determined by the keywheel pins at the beginning of each operation, must remain the same until its completion, even while the keywheels are displaced, and the guidearms must not prevent the keywheels from boing displaced.

Therefore, the guidearn assembly (54) here consists of two separate parts, the feeler arm (541), and the guidearm (542), which, when free, are held in a certain relative position to each other by action of the spring (544); this position can be changed during the operation, by imobilizing the guideara (542) in its position relative to the slidebar druii, and by retracting the feeler arn (541) from the keywheel.

The pin disk (51) carries a number of moveable pins (511) which are placed equidistantly in holes in a circle in the disk, a small distance below the outer circumference of the disk.

The number of pins is equal to the number of teeth in the driving gear (53) of the keywheel assembly. Thus the keywheel unit "42" has 42 pins and 42 teeth in its driving gear, etc.

The length of the pins is such, that, depending on which of the two positions they are placed in, they will project either to the right of the key disk, or to the left of the check disk (as seen when the keywheel unit is in its place in the machine). The pins (5111) projecting to the right of the key disk are active, those (5112) projecting to the left of the check disk are inactive.

The pins can only be placed in the desired position with the aid of a special tool. Thus the pins cannot be accidentally displaced when the disks are handled.

For the functioning of the guidearm in the machine CX-52, see the pictures 8 to 12 showing the different positions which the guidearm assembly (54) can take during the operation.

The pictures show the following parts:

- two keywheel unit bearing plates with pin disks (51), pins (5111) \& (5112) feeler arm (541) guide arms (542), with their springs (544) \& (58).
- the retractor bar (181) with the right arn (182).
- the guide ara locking bar (46) with extension (463) and right arm (462).
- the locking lever (45).
- part of slidebar drum shaft (31) with the cams (34) \& (35).
- the driving pinion (36).

The bearing plates (57) are shown positioned against the bar (16) of the baseplate (1). On all figures, the left key disk "29" is shown with an inactive pin (5112) opposite the feeler arm (541), and the right pin disk "31" with an active pin (5111) opposite the feeler arm (541).

In picture 8, which shows the starting position, i.e. before any movement has taken place, it will be seen that the cam follower (1821) of the lever (182) rests on the high portion of the cam (34), the lever (45) also rests on the high portion of the cam (35). The retractor bar (181) is thus in its lower position, and holds the feeler arms extensions (5411) away from the pins (5112, 5111) through the action of the retractor bar on the extension (5412) of the feeler arm - it will be seen that the feelems are a small distance away from the outer edge of the pins. The keywheels can therefore be rotated without interference from the guidearm feelers.

In picture 9 the operation has just started (the handlever (41) and has been pulled forward a small distance). The shaft (31) has turned only so much that the cam follower (1821) has entered the low portion of the cam (34), the retractor bar (181) is now in its high position, and the springs (58) have pulled the feeler arms (541) towards the pins (5111, 5112).

While the feeler arm of the right keywheel unit "31" will move only a small distance as it will strike against the active pin (5111), the left feeler arm will move an appreciable distance because it will not be stopped by the inactive pins (which protrudes to the left). The right guidearm (542) will therefore scarcely move, while the left guidearm will follow its extension (5411) and move towards the keywheel, away from the drum.

Picture 10 shows the next phase of the movement. The cam follower (1821) is still in the low part of the cam (34), and the composite guidearms (54) hold the same positions as in picture 9. The lever (45) has however reached the low part of the cam (35), and the locking bar (46) has taken its lower position. The upper part of the right guide surface arm (542) will be locked by the bar (46) which has an inverted U-form , while the left guide surface arm will stay outside the locking bar.

In picture 11 the locking bar (46) remains in its lower locking position, while the cam follower (1821) has entered the high part of the cam (34). The retractor bar has been pressed downwards, and both feeler arms (5411) have been drawn out of reach of the key pins.

These positions of the locking bar (46) and retractor bar (181) will remain unchanged during the displacement movement, and the keywheels will therefore be free to move, while the guide surface arms (542) will retain the positions which had been indicated by the initial position of the keywheels.

The movement of the feelers (5411) relative to the guide arms (542) can take place because there is a positive action on the guide arm (542) from the feeler (541) only in the forward movement (when the retractor bar (181) moves upwards); when the feelers are retracted [downward movement of the retractor bar (181)]they work only against the tension of the springs (544), which connect the feeler with the guide arm.

The action of a slide-bar, which carries the four types of teeth A B C and 0, on the keywheels, is shown on the picture 12 ( a and b ). On the right of picture 12a, a guide arm (542) has been immobilized by the locking bar (46), away from the slidebar drum, while on the right of picture $12 b$ the guide arm (542) has been locked in the channel portion of the locking bar (46), close to the slidebar drum. The guide arm in picture 12a has received its position because its feeler (5411) had registered with an inactive pin (5112), and the guide arm (542) in picture 12 b has received its position because the feeler arm (5411) had registered with an active pin (5111). An active pin will bring the guidearm close to the slidebar drum, and an inactive pin will cause it to stay away from the drum.

On the picture 12 a) and b), there are also shown one slidebar (38) with a lug (39), which registers with the guidec arm(542), and also the displacement mechanisms for four keywheels (5).

The slidebar is shown with one each of the four different teeth types which have already been described; $A, B, C$ and 0 .

We will find that in rotating the slidebar drum (3) in picture $12 a$ the slidebar will remain in the right position shown, and tooth type A will immobilize the keywheel driving gear $I$, tooth type $B$ will advance the keywheel driving gear II one step, tooth type C will advance the keywheel driving gear III one step, and tooth 0 will lock the keywheel driving gear IV.

In picture $12 b$, rotating the drum, the slidebar (38) has been caused to move to the left position, through the action of the guidearm (542) on the lug (39), and the tooth A will advance the keywheel driving gear I one step, tooth $B$ locks the keywheel driving gear II, tooth $C$ will advance the keywheel driving gear III, and tooth 0 will lock the keywheel driving gear IV.

These two examples will show the basic combinations which are possible with the use of the four types of teeth, and the action or non-action of the guidearms (542).
It should also be noted that normally only one active lug (39) is used on each slidebar (38), although there is nothing to prevent that in special cases two or more lugs can be placed on each slidebar.

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57 - The bearing plate (pictures 5 & 7,
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This has a notch (573) at its lower rear edge, which will engage with the retaining bar (16) when the keywheel units are slid into position in the grooves (103) in the baseplate
When put in place, the positioning shaft (59) is inserted through a journal in right bearing (4), through the hollow centers of the bearings (571) of the keywheel units, and then into the corresponding journal in the journal plate (29).
The keywheel units (5) will now be held firmly and correctly in their positions in the machine.

The shaft (59) will also, when fully inserted, protrude about 65 mm (2 $5 / 8^{\prime \prime}$ ) into the printer compartment, where it will function as an axle for the alphabetwheel unit (6).

When correctly inserted, the shaft is locked automatically in position.
6 - The alphabetwheel assembly (picture 5)

This unit is a composite device which consists of the following main parts:
$1^{0}$ The primary part:

- the operating knob (61)
- the gear wheel (62)
- the primary typewheel (63)
$2^{0}$ The secondary part:
- the secondary typewheel (64)
- the spacing pin (641)
- the gear wheel (66)

The secondary part is mounted on a tubular shaft, which extends towards the left and on which the primary part is rotatably mounted. The primary-typewheel unit is connected to the secondary-typewheel over a coupling with 26 teeth, which permits to connect the two parts to each other in 26 different relative positions.

An invisible spring keeps the two units in mesh, so that when the operating knob (61) is turned, both units revolve together. By pulling the knob (61) outwards, to the left, the two units are separated, and the two parts can be rotated independently of eash other. This feature is used in order to make it possible to set the two units in different positions relative to each other.

This is effected automatically for each operation if the knob F-V is set into position "V".

The following parts, which are placed on the alphabet wheel cover (2601) belong also to the primary part of the alphabetwheel assembly:

- the indicating disk (69), mounted in a circular recession in the lid (2601).
- the moveable index (691), in the center of the recession, which is integral with:
- the gear wheel (692), which is found under the lid and which meshes with the wheel (62) of the primary part of the typewheel assembly, when the lid is closed.

The purpose of the disks and the moveable index is to indicate the position of the primary type wheel. In order to obtain correspondence between the index (691), and the primary typewheel (63) it is
necessary that the gears (692) and (62) mesh correctly when the lid (2601) is closed and the machine is in position for operation.

In order to obtain this, it is first necessary (with the lid open) to put the index in the position, where its red index (6911) registers with the red dot in the recessed part of the lid. After this, press the button "0" (2602) and at the same time turn the knob (61) counterclockewise until stopped by the pawl (273). In this position, close the lid. It should be noted that one can open the lid only in this position, provided that the above mentioned correspondence has been established.

In order to change the relative position of the typewheels press the button "或" (2741) and turn the knob (61) counterclockewise until stopped; then pull the knob (61) out towards the left, and turn it in either direction until the moveable index registers with the letter agreed on to give the desired relative position.

III. CEARACTERISTICS AND CRYPTOGRAPHICAL POSSIBILITIES.<br>

The construction of the machine type CX-52 allows the following variations in the arrangement of the ciphering elements which are of importance for the cryptographical value of the machine.

10 The 32 bars on the drum are removable and interchangeable. The lugs on the bars can easily be changed. With the four possible types of teeth for the advancement of the keywheels, one could have $4^{6}=4096$ different arrangements for these teeth on the bars, viz. 4096 different bars. Normally only a limited number of different bars will be manufactured as a standard, but the user has always the possibility to order bars of his own choice.

We offer three different sets of bars, as a standard:

## Standard A:

## *)

*)


With standard $A$, each of the keywheels will be advanced a varying number of steps, from 1 to 5 , the program being determined by the placing of the lugs.

The arrangement of the lugs, of which there is a large number of suitable ones, has to be done in such a way that on one hand there shall be 26 different displacement steps available for the alphabetwheel assembly, and on the other so that the accidental formation of short key series will be avoided.

Standard B: bars No, 1-31: KBBBBBB
No. 32: KCCCCCC
With standard $B$, the keywheels will always be advanced together, the same number of steps, varying between 1 and 32. The following relation exists between the advancement of the keywheels and the displacement of the alphabetwheel assembly:
if the alphabetwheel assembly is displaced n steps, the keywheels will be advanced 32 - $\underline{n}$ steps.
N. 31: KOOCCCC

Standard C. bars No 1 - 30: KCCluuO No 32: KCCCCCC
This standard is only used, when machines type CXX -52 shail correspond with machines of earlier types, such as the $\mathrm{C}-446$ or the $\mathrm{M}-209$. It should be noted that in this case the keywheels $26,25,46,42,38 \& 34$ must be used, in the sequence now given. As the number of pins in the keywheels $46,42,38 \& 34$ is double of that in the corresponding keywheels $23,21,19 \& 17$, of the earlier types, the pin arrangements on the lastmentioned keywheels have to run twice on the firstaentioned ones. Speial instructions for the arrangement of the pins and lugs can be had on request.

In all cases, the total number of combination for the advancing of the keywheels, and the displacement of the alphabetwheel assembly is 64 .
$2^{\circ}$ There is a choice of twelve different keywheels, with the following number of pins:
$25,26,29,31,34,38,41,42,43,46$ \& 47.
The following six of the above twelve wheels are normally delivered with the CX-52 machines:

29, 31, 37, 41, 43, 47.
The number of possible arrangenents for the pins (active or inactive positions) is theoretically $2^{n}, \underline{n}$ being the number of pins in a given keywheel. Thus ab. $3 \cdot 3 \times 10^{7}$ for 25 pins and $1.3 \times 10^{14}$ for 47 pins. Even if certain combinations should be avoided, there will be an enormous number of different arrangements available. It should be noted that normally the number of active pins should be as nearly as possible $50 \%$ of the total number of pins, on each pin disk.
It is of interest to note that the six keywheels which are normally available with the machine can be arranged in 6! $=720$ different sequences.

The use of a larger number of keywheels than six permits a number of different arrangements, which rises rapidly with the number of keywheels available.
For instance,
the use of 7 keywheels permits
5.040 arrangements

8
20.150

9

10
11
60.480
151.200
332.640

12
665.280

With any six wheels, the change in their sequence in the machine is equivalent to a change in the arrangement of the lugs on the bars, and it should be noted that it is much easier to change the positions of the keywheels than those of the lugs.

The alphabetwheel-assembly is easily removed, and it is possible to use, either several different assemblies, with fixed types, or assemblies with rearrangeable types. In the latter case, when one uses a single alphabetwheel-assombly - which is normally done - one has the choice of $26!=4 \times 10^{26}$ different alphabets.

One could also use two different assemblies, one for the enciphering and the other for the deciphering operation. In this case, the number of possible alphabets would be 26 ! $\times 26$ ! $=$ $1.6 \times 10^{53}$. These figures are theoretical, but the number of suitable alphabet arrangeaents is infinitely larger than could be practically utilized.

The number of variable elements in the CX-52 machine are thus:

- the drum bars, with different tooth arrangements and with movable lugs.
- the keywheels with rearrangeable pins, and
- the alphabetwheels with variable alphabets.

All in all, the number of the different combination which can be utilized is practically unlimited, and offers to competent users practical means for the production of unbreakeable ciphers.

Note: The normal machine uses the normal alphabet A......Z, of 26 letters.

On demand a number of special arrangements can be obtained, such as:
$1^{0}$ - Machines for the ciphering of 30 signs instead of 26
$2^{0}$ - Machines for the ciphering of 10 numbers.
$3^{0}$ - Alphabetwheel assemblies, with fixed or rearrangeable special signs, permitting the ciphering:
a) with letters others than the normal $L_{\text {atin }}$ ones
b) with numbers, permitting the ciphering of numbers into numbers, or of numbers into letters.

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pictures 1 to 14
(027)

Fig. 1


Fig. 2



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Fig. 4


Fig. 5


Fig. 7

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Fig. 8





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Fig. 13

(027)

## Fig. 14



