The Enigma Machine

History of Computing

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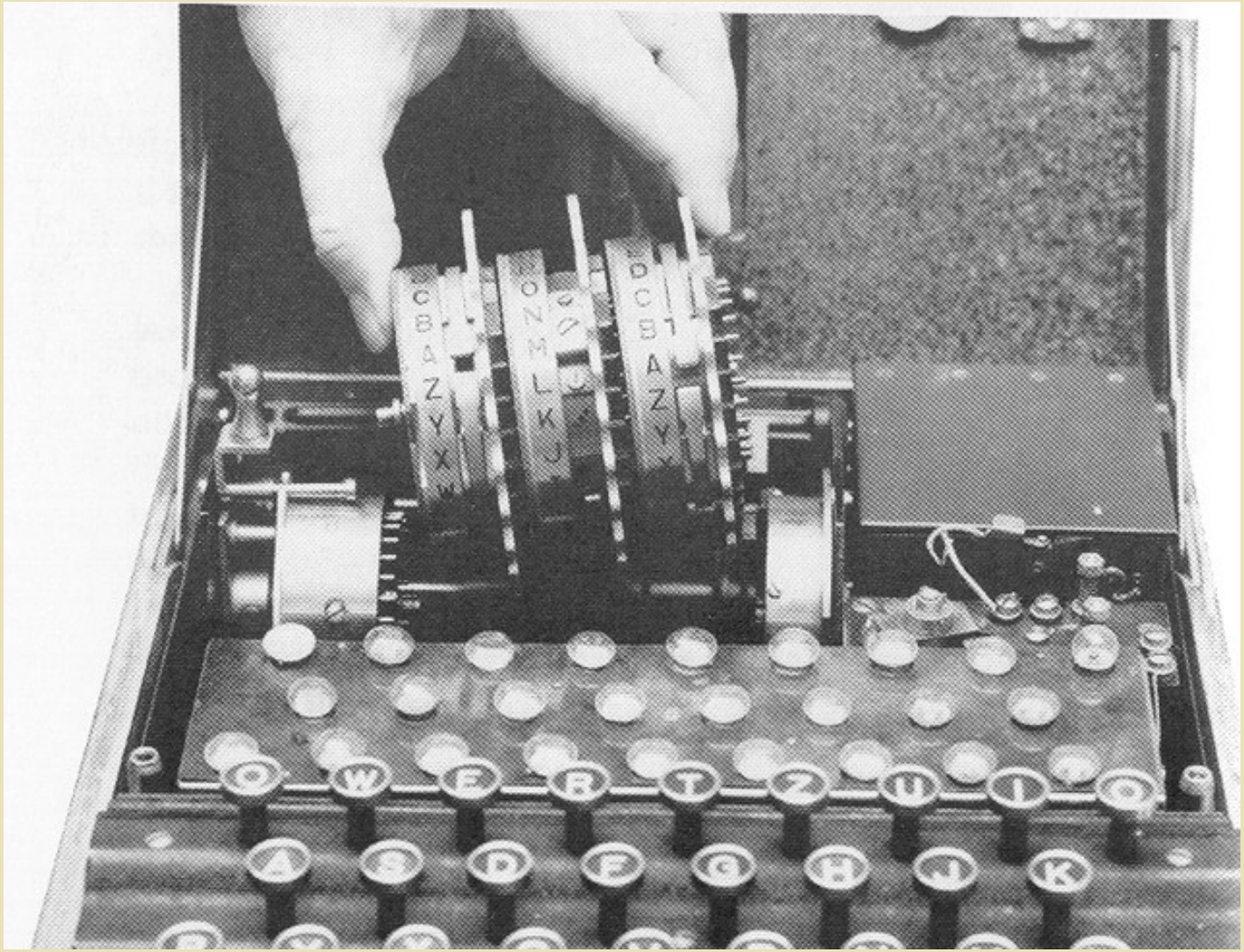
Invention of Enigma

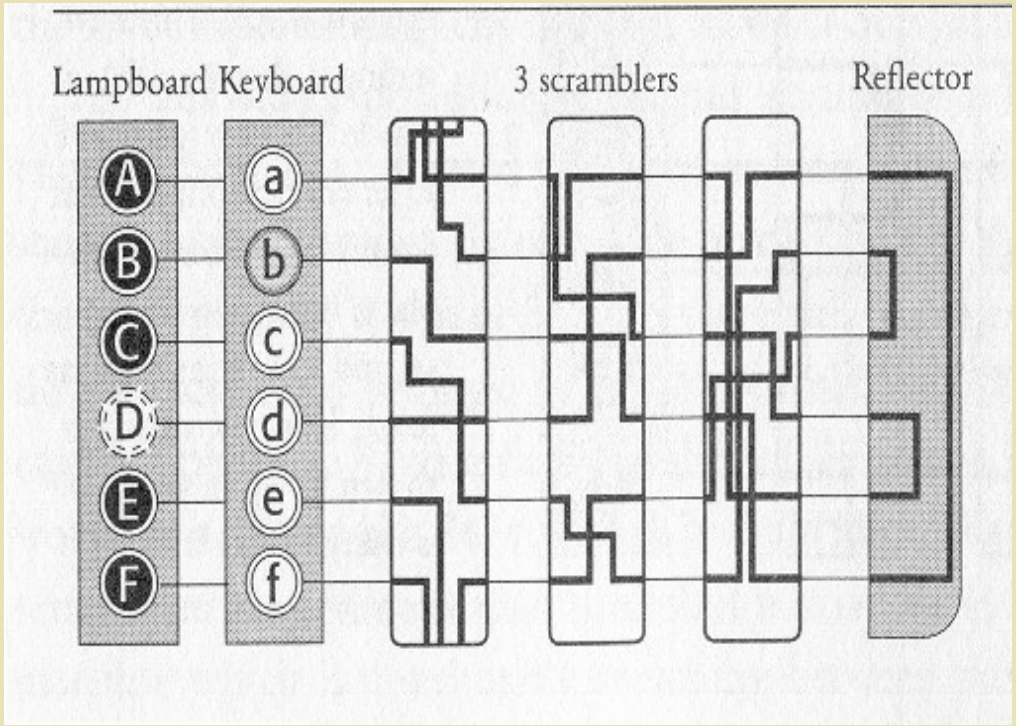
- Invented by Arthur Scherbius, 1918
- Adopted by German Navy, 1926
- Modified military version, 1930
- Two Additional rotors added, 1938

How Enigma Works



Scrambling Letters

- Each letter on the keyboard is connected to a lamp letter that depends on the wiring and position of the rotors in the machine.
- Right rotor turns before each letter.



How to Use an Enigma

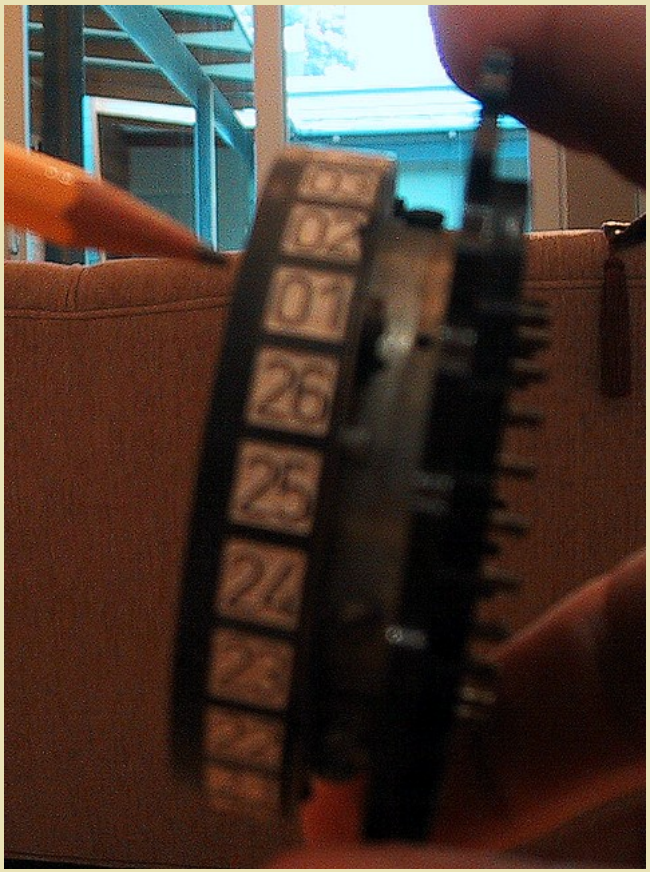
- Daily Setup
  - Secret settings distributed in code books.
- Encoding/Decoding a Message

Setup: Select (3) Rotors

- We'll use I-II-III

Setup: Rotor Ring Settings

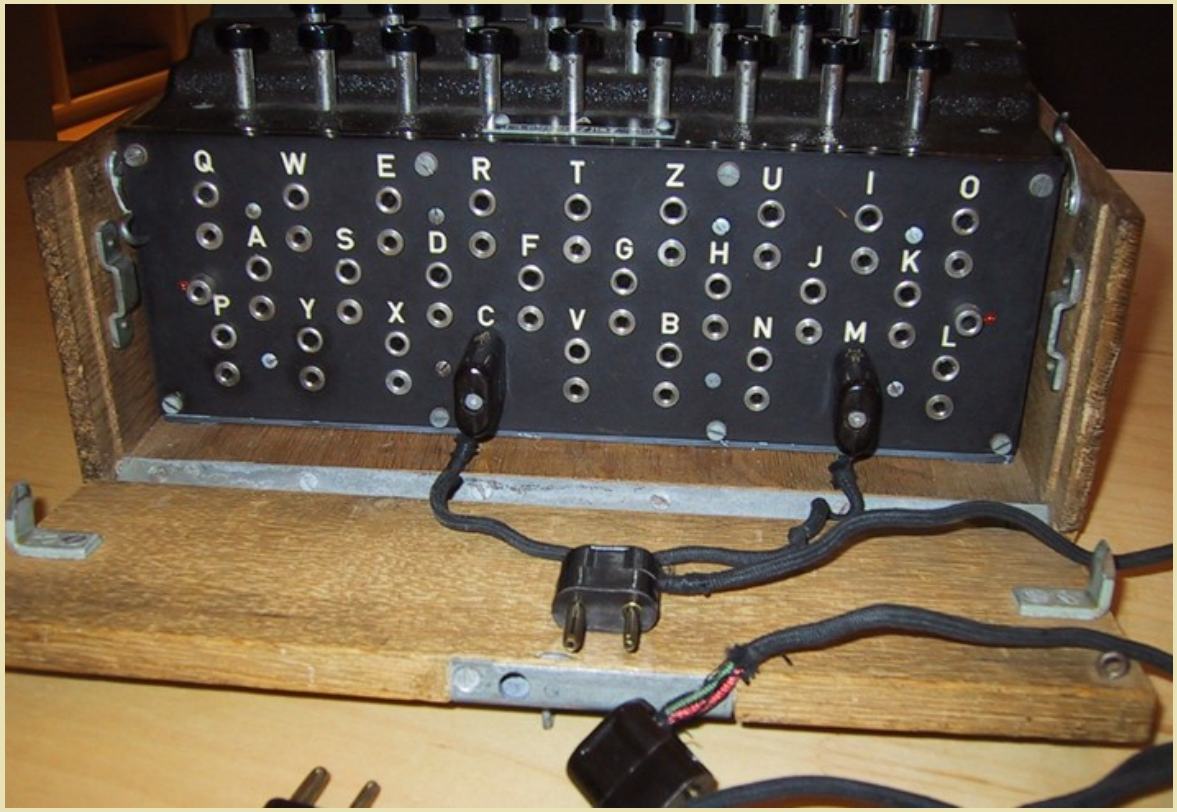
- We'll use A-A-A (or 1-1-1).



Rotor Construction

Setup: Plugboard Settings

- We won't use any for our example (6 to 10 plugs were typical).



Setup: Initial Rotor Position

- We'll use "M-I-T" (or 13-9-20).

Encoding: Pick a "Message Key"

- Select a 3-letter key (or *indicator*) "at random" (left to the operator) for *this message only*.
- Say, I choose "M-C-K" (or 13-3-11 if wheels are printed with numbers rather than letters).

Encoding: Transmit the Indicator

- Germans would transmit the indicator by encoding it using the initial (daily) rotor position…and they sent it TWICE to make sure it was received properly.
- E.g., I would begin my message with "MCK MCK".
- Encoded with the daily setting, this becomes: "NWD SHE".

Encoding: Reset Rotors

- Now set our rotors do our chosen message key “M-C-K” (13-3-11).
- Type body of message: “**ENIGMA REVEALED**” encodes to “**QMJIDO MZWZJFJR**”.
- Complete message is then: **NWDSHE QMJIDO MZWZJFJR**

Decoding: Initial Setting

- Setup is the SAME for encoding and decoding. Set rotors to “M-I-T” (13-9-20).

Decoding: Decode Indicator

- Type in message indicator: “NWDSHE”.
- Confirm it decodes to “MCK MCK” (a valid message key).

Decoding: Message

- Set rotors to “M-C-K” (13-3-11)
- Type remainder of message: “**QMJIDO MZWZJFJR**” becomes “**ENIGMA REVEALED**”!

A Paper Enigma Machine

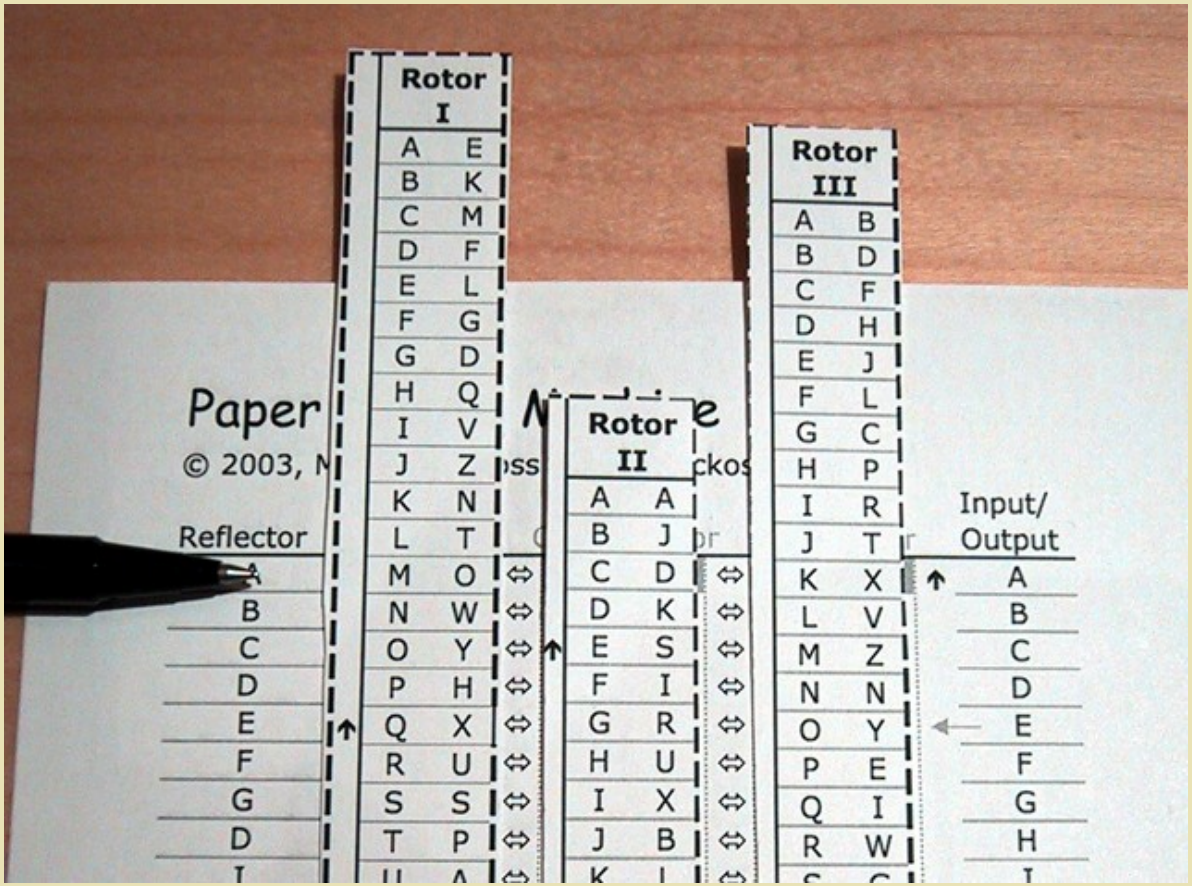
- Each rotor is modeled as a strip of paper; the electrical contacts are replaced by matching letters on left and right side of the strip.
- Keyboard and Lamps are replaced by a vertical list of letters on the right.
- Reflecting rotor is replaced by a matching group of letters on the left.
- Plugboard and rotor “ring settings” are not modeled.

Sample Encode

- Rotor order: I, II, III
- Rotor setting: M, C, K
- Encode the letter “E”

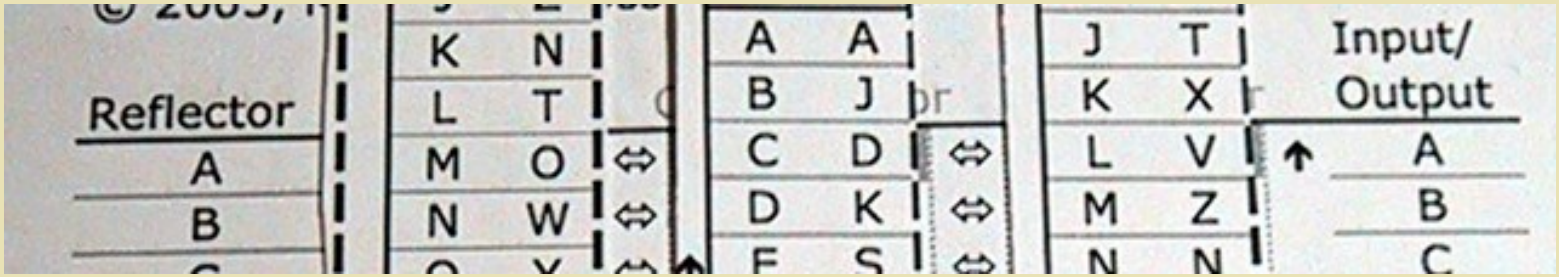
Initial Setting

- Rotors I, II, and III
- “Window settings” of “M-C-K”



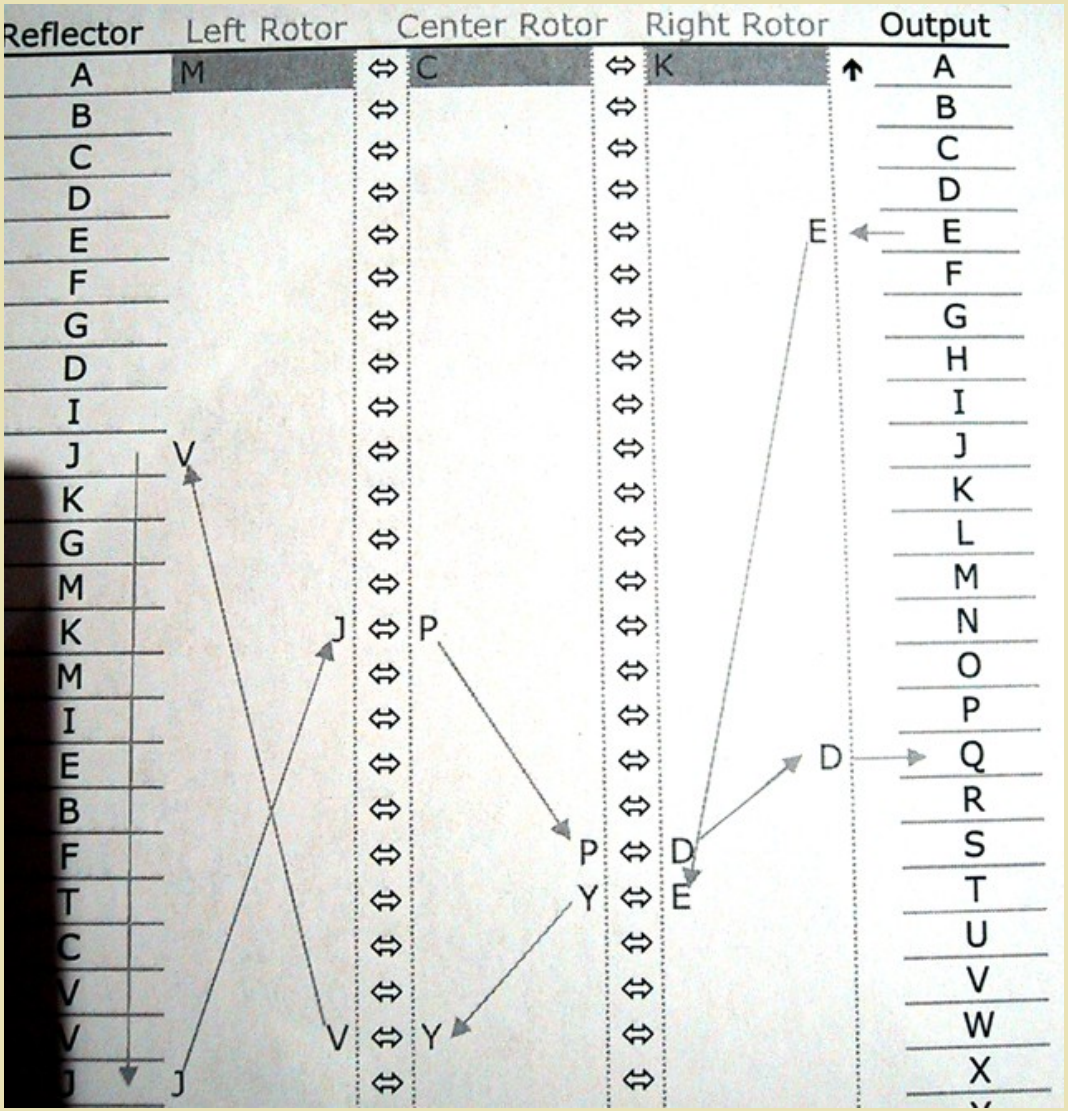
Encode a letter

- (First!) Advance the right-most rotor (III) by moving it up one row.



“Manual” Electricity

- Start at “E” on the right column.
- Trace through each rotor, matching like letters.



Rollover

- When the “notch” arrow reaches the window, move the wheel to it’s left up one row before encoding.
- When the center wheel arrow reaches the window, remember to move BOTH center and left wheels!

Breaking Enigma

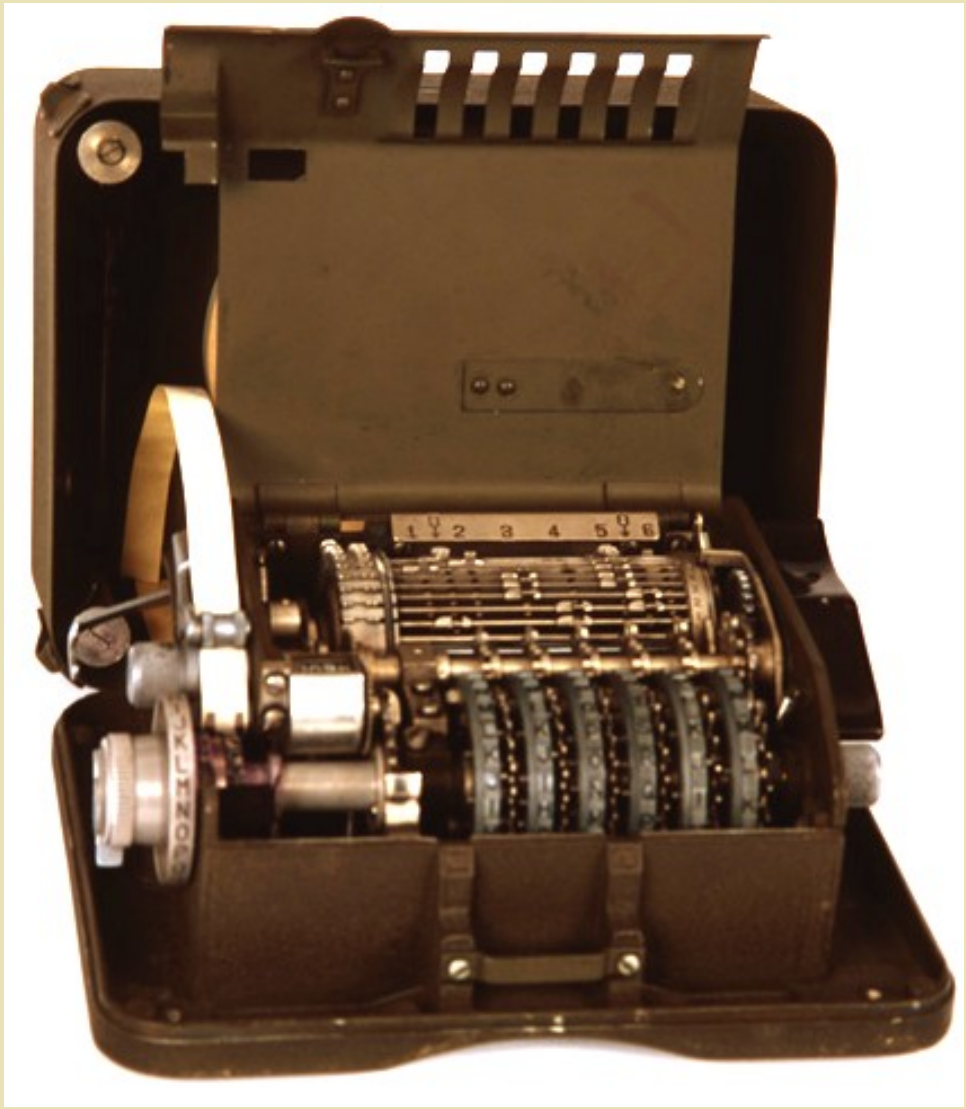
- Poles intercept commercial Enigma in the mail, 1928
- Recruit math students at Poznan University, 1929
- Poles (Rozycki, Zygalski, Rejewski) break the 3-rotor machine, 1932-1939
- Overwhelmed by 2 new rotors in 1938
- Poles hand over methods and machine copy to British and French in 1939
- Government Code & Cipher “School” created at Bletchley Park, 1939

Vulnerabilities

- Encryption of doubled indicators reveals information about rotor positions.
- Operators choose poor message keys (e.g., “BER”, “LIN”, “HIT”, “LER”, “JJJ”, “QWE”).
- Letter never encrypts to itself (allows known plaintext attack).

US Army, M-94 Cipher Device

US Army, M-209 (Hagelin)



Swiss, NEMA (New Machine)

Hagelin CD-57

Hagelin CX-52 RT (Random Tape)

Reihenschieber