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NATIONAL SECURITY AGENCY  
Washington 25, D. C.

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CATALOG OF ENIGMA CIPHER MACHINE WIRINGS

Compiled by

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June 1954

TECHNICAL INFORMATION DIVISION  
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~~TOP SECRET FROTH~~~~TOP SECRET FROTH~~INTRODUCTION

By means of the following report, it is intended to bring together under one cover the available Enigma cipher machine wirings used prior to 1946. As one of the principal targets of the combined Anglo-American cryptanalytic effort during World War II, the German Enigma machine was the basis for a considerable number of reports. These have been searched for pertinent material. The record of Enigma wirings is complex and varied due to the use of this machine by many countries in one of its basic forms, or with alterations and innovations. Included in this paper are rotor wirings given by the British, the U.S. Navy, Coast Guard, and Army. Some of these wirings are clearly and explicitly presented; others are briefly noted; many have been taken from work sheets, and bits of scattered, unassociated papers wholly intelligible only to their originators; some exist without accompaniment of explanatory data. Wirings and the machines to which they pertain will be discussed briefly under separate headings insofar as data is available.

Suggestions, critical comments, and additional sources of Enigma information are welcomed from readers for use in subsequent editions of this paper.

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I. BACKGROUND OF THE ENIGMA

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I. BACKGROUND OF THE ENIGMA

The Enigma cipher machine was the backbone of German high-level military cryptography. Its most outstanding performance was exhibited during World War II when a series of variations and ingenious innovations made it the leading target of Allied cryptanalysis. From its first appearance in the mid-1920's to the end of the War, it went through the following forms:

1. The O-Bar Machine, used by the German Fleet.
2. The Commercial or K Enigma, used by German commercial firms, the Post Office, the railways, and other miscellaneous German governmental agencies.
3. The Counter (Zahlwerk) Enigma, also referred to as the "G" and "Abwehr", used by Military Intelligence (Abwehr), by the Reich Security Office (Reichssicherheitshauptamt), and by military attaches.
4. The plugboard (Stecker) Enigma, used by the Supreme Command of the Armed Forces (OKW); the High Command of the Army, and in Army communications down through division; by the High Command of the Air Force, and in Air Force communications, down through group and sometimes squadron.
5. The plugboard Enigma (Schlüssel M), employing an additional rotor, used by the High Command of the Navy, and in

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Naval communications, including the submarine arm.

6. The plugboard Enigma with pluggable reflector D (Stecker mit Umkehrwalze D), used by the Air Force and proposed for the other Services.
7. The plugboard Enigma with Stecker Uhr, introduced by the German Air Force. This device was a security feature by which the stecker of individual messages on the same key could be varied.
8. The plugboard Enigma with variable notch rotors (Lueckenfuellerwalzen), proposed for the Supreme Command Armed Forces, Navy, and Air Force.
9. Cipher Device 39 (Schluesselgeraet 39), proposed for the Supreme Command Armed Forces, and the Army, Navy, and Air Force.

The last two machines do not enter into the period covered by this report. The variable notch rotors had not been distributed for general use and Cipher Device 39 was still in the development stage when the war ended.

The plugboard Enigma is contained in a wooden box about a foot square and six inches deep. When set up for use, it contains three wheels mounted between the endplate and reflector. It has a keyboard with 26 keys, labelled with the letters of the alphabet; a lampboard with 26 bulbs that shine through stencils on which the letters are marked; a stecker board; battery and switch. The lid of the box con-

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tains spare lamps, plugs, etc., and the whole is fitted with a handle for carrying. When a key is depressed, one or more of the wheels rotate one position and a current flows through the machine to one of the lamps. The letter appearing over the lamp is the enciphered result of the depressed key. The endplate is a ring of 26 terminals called entry points. In the unsteckered Enigma these are connected directly to the keys; in the steckered Enigma they are connected to the keys through the stecker board.

The stecker board has 26 pairs of sockets labelled with the letters of the alphabet, one from each pair leading to a corresponding key on the keyboard, the other to the endplate. This plate, if viewed from the side of the wheels and taken in anticlockwise order, is connected to the stecker board sockets in ABCD...Z order, this order being called the diagonal of the machine. Normally, the two sockets of a pair are connected together by a hidden spring. If a stecker is plugged into two pairs of sockets, say A and B, these springs are forced away, and the A key is connected to the endplate at a position which would otherwise be connected to the B key and vice versa. That A and B are connected by such a plug is expressed in the form A/B, or B/A. The effect of the stecker on the encipherment is as follows: if, at a position of the machine, A enciphers as R when there is no stecker, then at the same position with stecker A/B, R/X and perhaps others, B enciphers as X. A letter which is not steckered to another one is said to be self-steckered.

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A wheel has 26 terminals on its right face (as it sits in the machine) and on its left face 26 plate terminals. The plates are connected across by wires to the pins in random order. On the right side is a ratchet wheel and a large sprocket; on the left side is a metal ring, which can move freely relative to the wiring. This ring carries the letters A to Z (or the numbers 1 to 26) in order round its circumference, and is provided with one or two turnover notches on its extreme left edge. It can be held in any one of the 26 positions by a clip, the setting of which is called the ring setting.

The German Army and Air Force used five wheels, numbered I to V, each having one turnover notch in a position which varied from wheel to wheel. The Navy used three additional wheels, VI, VII, and VIII, each having two turnover notches at points diametrically opposite each other on the ring in the same positions on each of the wheels. When inserted in the machine, the wheels are mounted on an axle and the sprockets are held by pawls in the casing of the machine. Any three of the wheels in any order may be in the machine at a given time, and these are referred to as the right-hand, middle, and left-hand wheels. Parts of the sockets project through the casing of the machine, enabling each wheel to be rotated by hand and set to any one of the 26 positions. The position of the wheels is described by the letters on the rings which show through three windows in the casing of the machine; the sequence of the three letters which show are called the window position. The pins of each wheel are in contact

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with the plates to the right of the wheel, or, in the case of the right-hand wheel, with the endplate. The reflector has only 26 pins which are connected in pairs and are in contact with the plates of the left-hand wheel. Unlike the wheels, the reflector is not rotatable in the steckered Enigma.

The O-Bar Enigma came into use in the early 1920's. It had three wheels and no stecker, and the curious characteristic of 29 letters on its keyboard. Of these 29 letters, X always enciphered itself without the current entering the machine, and the 28 letters were enciphered in the normal manner. The rings of the wheels had 28 letters printed on them; curiously, the o-umlaut had been omitted and from this fact the machine derived its name. It was solved by Polish cryptanalysts and all traffic was read. The German Fleet discontinued its use in 1931 when it was superseded gradually by the "Schluessel M" or Navy plugboard Enigma.

The plugboard Enigma was the standard Service machine used by the Army, Air Force, and Navy. The Germans first used this machine with three wheels and six steckers. The reflector belonging to it was the "A" or "Anton". Having obtained photographs of the keys for three months, during which period the wheel-order remained unchanged, the Poles reconstructed the wiring of wheels 1, 2, and 3. Originally, three wheels, having one notch per wheel, were chosen from a set of five. Later, under German naval procedure, three wheels were chosen from a set of eight, five of which had one notch per wheel and three,

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two notches per wheel. The reflector went through changes from the "A" to the "B" and "C". The "C" was used for a few weeks only in 1940 on one Norwegian air frequency.

The old "B" reflector, which replaced the "A" in the summer of 1937, was abandoned by the Navy and a new "B", half its size, plus an additional wheel (Zusatzwalze) - the number 9 Delta or Beta wheel - were introduced 1 February 1942, making the Navy machine a four-wheel Enigma. The Beta wheel was so wired that when set at the letter A, the combination of it and the new "B" reflector would give an effect equivalent to that of the old "B" reflector, thus enabling holders of the four-wheel machine to continue communicating with holders of the three-wheel machines. On 1 July 1943, a tenth wheel, the Gamma wheel, was introduced. When this wheel was set at the letter A and combined with the new "B" reflector, the effect of the "C" reflector was produced. These last two additional wheels had no notches and were used interchangeably in the fourth wheel position. Subsequently, about 1 January 1944, the Air Force introduced the pluggable reflector "D" which caused considerable difficulties for Allied cryptanalysts. This form of the machine as employed by the Air Force used three one-notched wheels from a set of five. The plugging of the reflector formed part of the key and changed at first three times and later four times a month. At least two Army keys used the "D" reflector with a daily changing plugging, and it seems probable that it was introduced on one of them in 1943. The pluggable reflector was not used by the Navy.

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Still another version of the plugboard Enigma was proposed, using three from a set of five multiple- and variable-notched wheels called the Lueckenfuellerwalzen.<sup>1</sup> The reflector in this machine was a pluggable or non-pluggable fixed plate, as desired. These changes introduced an aspect of unpredictability in key change.

During the 1930's various patents were issued to German inventors for Enigma machines manufactured for sale in Germany and other countries. These machines were used mostly by German commercial firms for sending business instructions to their agents in other countries and could be bought freely on the open market. The Commercial or K Enigma was sold openly until about 1934. It was used in various versions by the Croatian puppet government, the Spaniards, Italians, the Swiss, and, of course, by the Germans themselves. It had three single-notched wheels, a settable reflector, and a fixed input. Many countries rewired the wheels for greater security. After the Nazis acceded to power the machine was withdrawn from the market.

The years 1936 to 1939 cover the period of the Spanish Civil War. When it started, the A Commercial Enigma, an unsteckered machine, was already in existence. A serial number accompanied the A on these machines. They were so marked by their manufacturer, Heimsoeth and Rinke of Berlin. If no letter followed this serial number the machine

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1. The compiler tested a set of captured Lueckenfuellerwalzen (in the NSA Museum) for wiring; it was learned that these rotors had the same wiring as the standard military machine.

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was usually a standard Army model used by the German Army, the Schutzstaffel, and the German Air Force. If a Greek letter "Alpha" or "Delta" followed the serial number (e.g., A-246176a) the machine was a standard model returned to its manufacturer for special rewiring. The purpose or destination of these machines has not been determined.

The Italian "K" Naval Enigma was an improved version of the "A" Commercial. It differed from the "A" in that the notch on each of its three wheels was attached to the ring of the wheel instead of to the wheel itself. It was used by the Spaniards during the Spanish Civil War and by the Italians for naval communications between Rome and the Italian colonies. In this capacity it was called by the British the "Italian K" or the "K Italian Naval Enigma".

During the summer of 1937 the German Intelligence Service and its subsection, the Security Service, referred to respectively as "Abwehr"<sup>2</sup> and "Sicherheitsdienst"<sup>3</sup>, were sending secret agent traffic from Germany on various networks throughout Europe. This traffic was being intercepted by the British at GC&CS. Mr. Knox of GC&CS is credited with having been the first to solve messages from this traffic and with the setting up of a section for the purpose of continued cryptanalytic attack on the system. This unit was called the "Illicit Series Knox

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- 2. Amt, Auslandsnachrichten and Abwehr or "AAA", (headed by General Canaris) a part of Hitler's Oberkommando der Wehrmacht (OKW), the Military High Command responsible for coordinating and controlling the Army, Air Force, and Navy in the general conduct of the war.
  - 3. The Sicherheitsdienst (SD) headed by Himmler; the principal intelligence organization of the German Nazi Party.

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Section", thenceforth referred to as ISK. Since the Italian and Spanish traffic, discussed in the previous paragraph, presented the same kind of cryptanalytic problem as the messages coming from Germany, though entirely unrelated, ISK also took this traffic under surveillance, and during the Spanish Civil War solved the Italian K Enigma. By this time, the reflector known as "Anton" had been changed in the standard Service machine to "Bruno".

From the earliest days of World War II (1939-1945) Berlin maintained an extensive network with the main Balkan cities - Vienna, Belgrade, Bucharest, and the whole of eastern occupied Europe as far afield as Salonika and Warsaw. Previously, messages already solved by the British and identified as coming from the Abwehr had been enciphered in a non-machine system. Suddenly towards the end of 1939, Enigma traffic, related to these earlier messages, began to appear on a Berlin to Madrid net and consequently was recognized as also coming from the Abwehr. This traffic involved many keys. Abwehr agents also appeared in Turkey during the early part of the war. They sent numerous messages to the Balkans and to Berlin; throughout the war the Abwehr kept up extensive communications with Madrid and Lisbon.<sup>4</sup>

At the end of the Spanish Civil War, the Spanish used their K

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4. It was during 1939 that Cipher Device 39 (Schlüsselgerät 39) was proposed for the Supreme Command Armed Forces, Army, Navy, and Air Force. But there were so many alterations and time difficulties involved in getting this machine under way that it actually never left the development stage.

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Enigma for communications with the Naval attache and the Italians sent theirs to stations in the colonies - Asmara, Rhodes, Tripoli, Bengazi, Leros, and Tobruk. The Enigma referred to by the British as "Italian Naval II" was used for this new Italian traffic and ISK began work on it in April 1940. During this year also, the British recovered the "C" (Caesar) reflector used in the Naval Enigma. This reflector was never used with Army or Air Force keys.

The Abwehr at this time was using ten steckers and eight wheels. In the course of World War II, it and the Sicherheitsdienst used nine different Enigma machines.<sup>5</sup> In May 1941 they introduced the Canary Islands Enigma for messages passing between Cisneros and Paris. ISK began attacking these. By December Abwehr traffic had reached a high peak, enabling such good cryptanalytic attack that from then on to the end of the war most of the important Enigma traffic sent by the Abwehr and Sicherheitsdienst was read consistently. Towards the end of the war, an important network of mobile Abwehr units appeared in France and the Low Countries. This network used a key of its own and the decrypted messages provided one of the most important sources of cribs for attack on other Abwehr Enigma systems.

On December 7 1941 (Pearl Harbor Day), the A-837, an old model three-wheel lampboard Enigma, was seized by the U.S. Treasury Department on the premises of CHEMWYCO in New York. It was thought that the

5. These were the Group II, GGG, KK, GREEN South American, Canary Islands, SD, RED South American, KD, and the Service Enigmas.

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