HEBERN TYPE WIRED ROTOR DEVELOPMENTS BLUE ROTOR

This 26-point rotor was the basic rotor used in U.S. cipher machines during World War II and up to the late 1950s. The Blue Rotor was a typical Hebern rotor. It was used in the SIGABA/CSP-889 series of equipments, of which about 11,000 were made; the CSP 1700 series of equipments, of which about 2,000 were made; and the ASAM 2-1 series of equipments, of which about 2,500 were made. It had the important advantages of being siple and rugged with very few parts, but it was relatively large (3-1/2" diameter x 5/8") and heavy (6 oz.). The fact that the Blue Rotor required separators in the maze, thus doubling the number of electrical contacts per circuit path through the maze, required greatly increased power to cope with the increased circuit resistances thereby created. The manual rewiring required of this rotor was a relatively slow process, and at critical times in the history of its use the rotor wiring out barely kept up with requirements. In the "Colmar Incident"[1] of World War II, the wiring of the Blue Rotors and replacement rotors in use in the European Theatre of Operations were considered compromised. This necessitated the special assignment of the equivalent of a battalion of men working on a crash basis to rewire Blue Rotors to permit continued use of the cipher equipment in that area. Another disadvantage of the Blue Rotor was the fact that other than rewiring it, the only

WHITE ROTOR

On order to give the Blue Rotor a greater number of a modification was introduced in March 1952. Existing Blue Rotors were modified to accept an alphabet ring and a notch ring for controlling rotor stepping, both of which could be rotated with respect to the main rotor body and which could be freely interchanged from one rotor body to another. This modified Blue Rotor was called the White Rotor.

YELLOW ROTOR

As part of the development of the TSEC/KL-47 by the Navy, a small, 26-point Hebern type rotor, designted the Yellow Rotor, was built. However, for reasons of economy and logistics, NSA

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decided to modify the KL-47 to accept the existing Red Rotors[1] thus negating the need to go into production on the Yellow Rotor.

ENIGMA-TYPE WIRED ROTOR DEVELOPMENTS GREEN ROTOR

Near the close of World War II a 26 point Enigma-type rotor was developed for use in a small, battery powered cipher device known as the SIGFOY (M-325). This equipment was never used operationally, but an improved version of its rotor, known as the Green Rotor, was employed in an on-line, teletypewriter equipment called the SIGNIN. A rotor of the Enigma-type, with the consequent elimination of separators, made possible a much smaller maze than in earlier U.S. electro-mechanical cipher equipments, and the rotor was designed to be rewireable without soldering to speed up the wiring process. This was achieved by making it possible to shift some of the internal mechanisms by hand into any one of 26 positions. Four hundred and fifty SIGNIN's were produced by the end of World War II, and some were still in operational use as late as 1958.

RED ROTOR

The development of the Red Rotor represented the major U.S. effort in this field in the post World War II era. A Series of cryptologic studies initiated in February 1946 resulted in the decision to use a 36-point rotor with rotable notch rings and alphabet rings as the basic cryptographic component of two new cipher machine developments, an off-line literal security equipment, TSEC/KL-7, and an on-line teletypewriter equipment, TSEC/KW-9. The 36-point rotor was chosen in order that a common rotor could be used in both systems.

Technicians working on these systems encountered two major problems during development of the Red Rotor. One was contact resistance build-up, and the other was dimensional instability of the plastics being used. The Red Rotor used berrylium copper and, in operation, particles wore off which turned into copper oxide. Copper oxide is very abrasive; this caused the wear effect to be cumulative. It is also non-conductive, and the build up on contact points caused interference with proper operation of the cipher maze. Problems with the plastics used in the Red Rotors came about because of the wide tolerances of parts. These conditions were attributed to the

methods used in the molding process, as well as the environmental situations in which the equipments were used.

Starting in 1946, four contractors were assigned to studing Red Rotor developmental problems. During the following ten years more than a million and a quarter dollars were spent on research relating to the Red Rotor and its successor, thus Orange Rotor. A thorough evaluation of nearly 200 contact materials did not uncover a better material for practiced application than the original material, berrylijm copper; and a lengthy search of plastic compounds showed that the one used in the original Red Rotor design was the most suitable for the purpose. Follow-on equipment modifications and improvements enabled the Red Rotor to be fully acceptable in all of the machines designed to use it, namely, the TSEC/KL-7, TSEC/KL-47, and TSEC-KW-9.

ORANGE ROTOR

Orange Rotor was a Red Roter with some changes. The principal change was that a metal hub was added to positively space the rotors, the alphabet ring was mde rotable without having to remove it from the rotor, and the notch ring was made wider and sturdier. The Orange Rotor went into production in August in 1956 and at that time was designated as the standard 36-point wired rotor.

BROWN ROTOR

Development of the Brown Rotor, undertaken by the Navy with NSA approval, was completed by the end of 1954. The differences between the Brown and the Red Rotors were principally in detail design. Because it was so basically similar to the Red Rotor, for which production tooling had been completed, the Brown Rotor was not considered for production.

PRINTED ROTOR DEVELOPMENTS

In 1946, as a parallel approach to the development of the Red Rotor, technicians initiated a study on the feasibility of using a printed rotor to melt existing requirements. In the laboratory models that were built, the printed circuitry was etched on the rotor body itself. The aim was to have printed circuit rotors for the TSEC/KL-7 and TSEC/KW-9 be the same in physical appearance and outside dimensions as the wired rotors. In this way, complete interchangeability of printed

circuit and wired rotors in the machines using the Red Rotor would be possible. In view of this, the basic printed rotor approach was dropped and a development was persued in which mixed wiring inside a Red Rotor was replaced by a plastic disc containing printed mixed circuitry. Outward appearance of the rotor with the printed circuit insert was the same as that of the rotor with mixed wiring. At the time that the decision was made to go into production on the TSEC/KL-7 and the TSEC/KW-9 because of the emergency brought on by the Korean War, a decision also had to be made on whether to go into production on the wired Red Rotor or on the printed circuirt insert. The users decided that since they had invested considerably more time in testing and developing the wired rotor, they would proceed with that choice. Development continued on the printed circuit disc, but at a low priority, and was concluded in 1953. NSA used the pilot equipment for experimental and educational purposes for awhile, but ultimately discontinued the project.

PNEUMATIC ROTOR DEVELOPMENT

In 1949, a pneumatic rotor was developed for use in the TSEC/KL-17, a small, keyboard operated literal cipher machine requiring no source of external power other than manual. This rotor was basically on Enigma-type rotor in which the mixed electrical wiring was replaced by air passageways. Pneumatic circuits, instead of electrical circuits, were established through the rotors comprising the maze.

By 1958 there were no plans for further contractual research and development activities on wired rotors. On the basis of past results technicians concluded that no significant improvement in the wired, 36-point rotor could be expected, either in the basic design approach of the Orange Rotor, or in more radical changes to that design. Local research continued at NSA on a low priority basis whenever an approach seemed to hold sufficient promise of marked improvement over the existing designs.

One effort which was continued for awhile involved a search for a conductive plastic. This was researched by the Markite Corporation and showed promise of resulting in a plastic to replace the metal contacts being molded into the plastic rotors. It was felt that the problems encountered by the differences in expansion between metal and plastic in the rotors could be alleviated by the

use of conductive plastic parts, and possibly a much smaller rotor could be achieved. This project, designated CALLIOPE, was eventually dropped.

Work on printed rotors for use in the TSEC/KL 98 and the TSEC/KL-3 continued. This effort resulted in a rotor for use in low echelon, low speed, manual devices. The use of this rotor in power driven quipment was evaluated through its application in the TSEC/KL-7 modification aimed at achieving interoperability with the TSEC/KL-17.

Termination of the studies on conductive plastics and printed rotors signalled the definite de-emphasis of rotors as a major cryptographic tool of general applicability in communications security equipment.

Rotor Development, Post World War II

Rotor	Manufacturer	Covered Fiscal Years
Red/Orange Rotor	Molded Insulation Co.; Minneapolis Honeywell Regulator Co.; American Phenobic Corp.	1947 through 1956
White Rotor	American Molded Products; Lundquist Tool and Manfacturing Co.	1952–1953
Printed Rotor	Melpar Inc; General Mills, Inc.	1954 through 1957
Flammable Plastic (for a plastic suitable for rotor use which would make it possible to readily destroy rotors in an emergency by incendiary means)	Esselen Resarch Division of U.S. Testing Corp.	1952–1953
Penumatic Rotor (for KL-17)	Corning Glass Works; Mycalex Corp.; Pure Carbon Co.	1954–1957
Blue Rotor	National Scientific Labs; Sterling Eng. Co.	1954–1956
CALLIOPE (development of a conductive plastic for rotors	Markite Co.	1956–1957

HIGH AND MEDIUM GRADE CIPHER MACHINES IN USE