The Hagelin - Gretener Cipher Teleprinter

The Hagelin - Gretener cipher teleprinter is an apparatus similar to the standard teletype machine, operating on the start-stop principle, which accomplishes automatic encipherment of [redacted] electrical impulses on line. Messages at both ends of a communications link appear in plain text or unenciphered form. The principal feature of the machine is the key-generating unit; this unit may be used with teleprinters employing the international or Baudot five-element code, or with the ETK-teleprinter, a machine invented by Gretener using a fourteen-element code. In the latter machine, each plain-text symbol (letter or numeral) is printed by forming a combination of one to five signs selected from a set of fourteen available elements. These fourteen elements are coaxially arranged in the printing part of the mechanism and are selected according to the particular plain-text character key which is depressed. In the cipher unit devised by Hagelin and Gretener, the generation of key under the fourteen-element code introduces a number of combinations which is considerably greater than is possible with the Baudot five-element code. Thus, after the plain-text character (one to five elements) has been added to the keying character (one to fourteen elements), according to the [redacted] non-Vernam rule for combining marks and spaces, the resulting cipher character may be composed of one to fourteen elements in 2^{14} or 16,384 minus two possible combinations. Of these, only about forty are readable symbols (letters and numerals); the remainder are not readable and, if produced in printed form, would appear as meaningless characters. Like the teleprinter, the key generating mechanism operates

on the start-stop principle. Through one revolution of the control shaft, the teleprinter and key generator run synchronously, the teleprinter producing the printing impulses (at its own terminal) and the generator emitting the keying impulses; both signals are combined on the fourteen levels and transmitted as an enciphered signal over a line or by radio. Decipherment and plain-text printing take place through similar apparatus at the receiving station. In the particular embodiment shown for use of the fourteen-element code, the machine operates on the neutral or single current system (current or no current), in contrast to the polar system, in which there is constant flow of current, during both marking and spacing intervals, but in opposite directions.

The generation of cipher key for this machine is accomplished through the medium of fourteen condensers. These condensers are part of a circuit consisting of a chain of fourteen polarity reversers, the chance operation of which determine whether a condenser is to be charged or not. Each condenser leads to one segment of the distributor, where the charge (or no charge) is taken off in sequence by the rotating brush and carried to the mixing circuit. Here the cipher key impulses are added to the plain-text impulses in the conventional manner to form the enciphered signal. The unit which randomly determines the condensers to be charged includes fourteen variable pin rotors of different sizes. (As shown in the descriptive write-up provided by the company, these wheels have 29, 31, 32, 34, 37, 38, 39, 41, 42, 43, 44, 45, 46, and 47 positions, and are not prime-sized to each other.) The pins, which can be slid axially by hand, project from the sides of the rotor, just below the periphery, either to the left or to the right. Each pin rotor

controls, through two feelers, four make and break contacts, of which two are mounted on one side and two on the other side of the rotor body. The two make and break contacts on the right side are combined into one double make and break contact (designated by the letter A); there are fourteen such contacts, each controlling one of the fourteen polarity reversers in the key generating circuit. The two make and break contacts on the left side (B and C) function as individual make and break contacts; contact B controls the operation of a (stepping) magnet associated with each pin rotor, and contact C operates to bring its individual condenser into connection with the positive or negative branch of the polarity reversing circuit. To insure that the position of the contacts on one side of a rotor will not be complementary to the position of the contacts on the other side, (a condition that would result from the use of a single reading station), the feeler associated with each set of contacts is placed on a different level. In the descriptive example, the feelers are mounted one pin division apart. In order, further, to break the rule that a pin, once it has been set, will activate only those contacts on its own side, single pins, e.g., one or two pins on each rotor, are made long so that they project on both sides of the rotor body, and other single pins are made short so that they project neither to the right nor to the left. Of course these two types of pins are not settable.

The variable pin rotors do not step regularly. Instead, their dilated motion pattern is obtained by interlockingly connecting the fourteen control magnets through contacts B. With each depression of a keyboard character, a universal bar is caused to swing away from a lever linked with each rotor. This lever, impelled by a spring, causes its associated pawl

and ratchet to move the rotor forward by one pin division. If, however, an armature has been lowered by an energized control magnet, depending on the positioning of its make and break contact by an active pin, then a blocking effect takes place, and the pin rotor is not permitted to advance.

The cipher circuit now consists of a chain of fourteen polarity reversers, the action of each of which is dependent on the influence of a right hand rotor pin on contact A. Inserted between each two polarity reversers, a condenser is brought into connection with the positive or negative branch of the polarity reverser chain through the action of contact C. All condensers are connected on one side in series and to the negative pole of the input. These condensers may therefore become charged or not. Whether condenser no. 1 is charged depends on the position of its related contacts A and C. Whether condenser no. 4 is charged depends on the positions of the first four contacts A and no. 4 contact C.

The input to the chain of polarity reversers takes place through a rotary feed switch. The chain of polarity reversers must not form a closed circuit and is therefore broken at irregular intervals and at different points in the circuit by means of a rotary separator switch. Both rotary switches are mounted on the same shaft as the variable pin rotors; the switches rotate in opposite directions with relation to each other. The irregular stepping of the rotary switches is dependent on separate control magnets, which, in turn, are controlled by variable pin rotor contacts B. The descriptive write-up on this version of the machine does not specifically identify these contacts, but it is evident

that they may be any of those among the fourteen available contacts, used either singly or in a multiple arrangement. A separate polarity reverser, through which current is introduced into the reverser chain, is controlled by one of the variable pin rotors (not specifically identified) through a relay whose control magnet is constantly without current. This rotor, therefore becomes a fast wheel, stepping each time a key is struck, and prevents a condition in which all the variable pin rotors stand still, i.e., all the control magnets are energized.

If, for example, at a given setting, the rotary feed switch is at polarity reverser no. 2, and the rotary separator switch has broken the circuit between polarity reversers nos. 7 and 8, then condenser no. 7 will receive its charge (or no charge) through the lead-in polarity reverser and reversers nos. 2,3, 4, 5, 6, and 7, and no. 7 contact C. If, when the next character is struck, the feed switch stands still while the separator switch advances one step (so that the separation of the chain of polarity reversers is between reversers nos. 6 and 7), then the charge of condenser no. 7, after the next key is struck, depends upon the lead-in polarity reverser and reversers nos. 1, 14, 13, 12, 11, 10, 9, 8, and 7. In this way, the charge of any condenser is dependent on a constantly changing number and a constantly changing configuration of rotor pins.

As the sixteen wheels are aligned at the start of a message, the condensers will become charged or not, according to the particular configuration of pins and their effect on the various single and double make and break contacts. During the single revolution of the control shaft of the cipher unit, while one message character is being enciphered

and transmitted, the advance of the variable pin rotors must take place simultaneously. The latter movement will result in a change of positions of the contacts A, B, C. In order that, despite this change, the condenser charges may remain constant during a complete revolution of the collector brush on the control shaft, all condensers are cut off from the variable pin rotor contacts C by a set of cam contacts shortly before the start and are connected up again shortly before the stop. The condensers thereby store their charges for a sufficient interval.

Additional variation may be introduced into the cryptographic circuit by arranging for the following changes of wiring:

Interchanging the polarity reversers so that a new sequence is formed;

interchanging the order of contacts C in the chain of polarity reversers;

interchanging the order of the storage condensers in the chain of polarity reversers;

interchanging the order of the control magnets (each of which is associated with a specific variable pin rotor) among contacts B.

Accordingly, an initial random wiring is selcted for each of these components, and enclosed within a rotary permutation switch. Each of these switches has fourteen positions and is normally set by hand; once set, the switches remain fixed in their positions for one or more messages. Their rotation, therefore, becomes equivalent to a slide. As a further variation, the descriptive write-up cites the possibility of employing two or three of each type of the permutation switches and connecting them in series (similar to a bank of wired rotors), all of them to be set manually.

In another variation of the circuit, which imposes some major changes in the wiring, the write-up discusses a plan that eliminates the two rotary switches (feed and separator) and the hand-set permutation switch that interchanges the control magnets. The remaining three permutation switches now have twenty-eight divisions, with their internal wiring changeable by plugging. Two of these switches, those for interchanging the order of the contacts C and the order of the condensers, are mounted on the shaft with the variable pin rotors and are subject to irregular stepping by having their control magnets come under the influence of pre-selected contacts B. The third permutation switch, for interchanging the polarity reversers, is set only by hand and remains fixed thereafter. The input of the feed voltages into the chain of polarity reversers now occurs at four arbitrarily selected points. From time to time at the feed inlet, the chain of polarity reversers is separated by cutting off the interchangeable leads. (The method for accomplishing this separation is not clear, since the write-up states that the separator switch is eliminated in this version of the machine.) In this way, there arise four distinct chains of polarity reversers, whose composition is different from the wiring of the polarity-reverser switch at each switch position. The (jack and plug) connections of the fourteen control magnets as well as the connections of the control magnets of the two rotary permutation switches with their related contacts B are made by hand at the time that the keying elements are set up in the machine. No permutation switch is provided for this purpose. To guarantee a constantly-changing configuration of pins, the fourteenth contact B is controlled by a variable pin rotor whose control magnet is permanently without current, i.e., this wheel always steps.