June 18, 1963 J. D. RICHARD 3,093,994

RECORDING SECURE LOCKING SYSTEM

Filed March 3, 1961 2 Sheets-Sheet 1

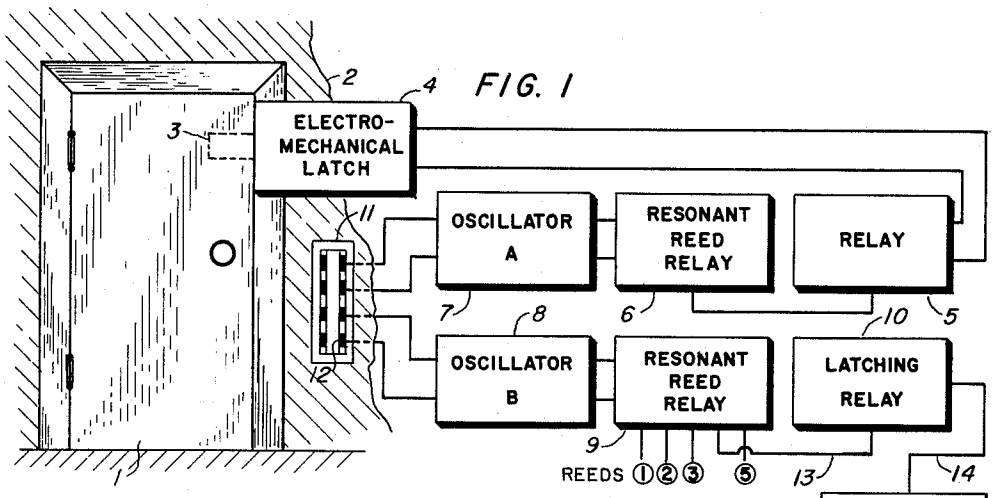


FIG. 1

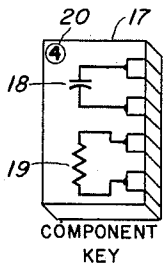


FIG. 2

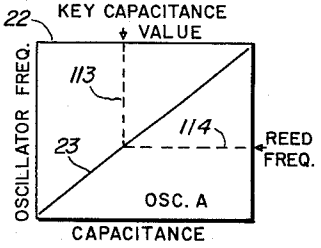


FIG. 3

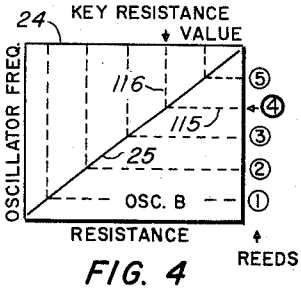
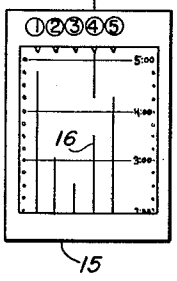


FIG. 4



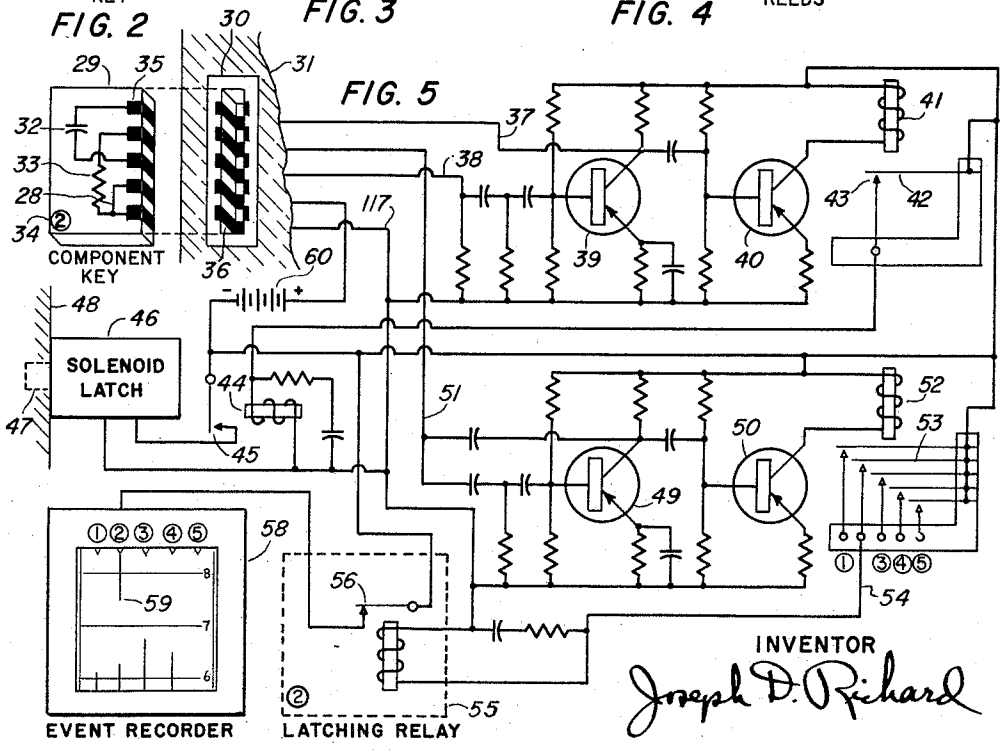


FIG. 5

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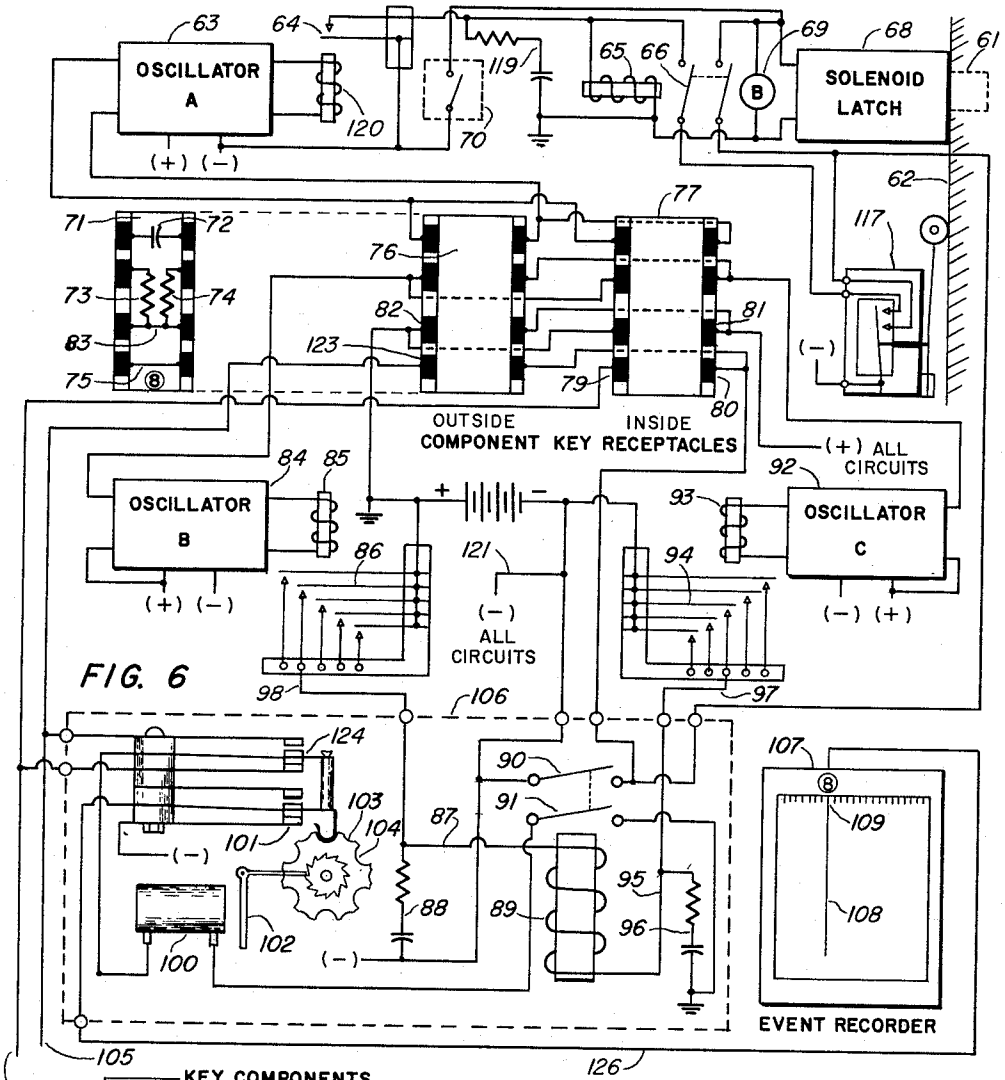


FIG. 6

KEY COMPONENTS

FIG. 7

KEY NO.	C1	OSC. A FREQ.	R1	OSC. B FREQ.	R2	OSC. C FREQ.
1	.06	346.6	10 K	200.0	5.4 K	368.5
2	.06	346.6	10 K	200.0	5.1 K	391.8
3	.06	346.6	10 K	200.0	4.8 K	416.3
4	.06	346.6	10 K	200.0	4.5 K	442.6
5	.06	346.6	10 K	200.0	4.2 K	470.5
6	.06	346.6	9.5 K	212.6	5.4 K	368.5
7	.06	346.6	9.5 K	212.6	5.1 K	391.8
8	.06	346.6	9.5 K	212.6	4.8 K	416.3
9	.06	346.6	9.5 K	212.6		
						416.3
24	.06	346.6	7.8 K	255.4	4.5 K	442.6
25	.06	346.6	7.8 K	255.4	4.2 K	470.5

FIG. 8

REED RELAY A (1 REED)	REED RELAY B (5 REEDS)	REED RELAY C (5 REEDS)
346.6 c/s	200.0 c/s	368.5 c/s
	212.6	391.8
	226.0	416.3
	240.2	442.6
	255.4	470.5

INVENTOR

Joseph D. Richard

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RECORDING SECURE LOCKING SYSTEM

Joseph D. Richard, 3569 Loquat Ave., Miami 33, Fla.

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7 Claims. (Cl. 70—434)

The present invention relates generally to lock and key systems. More specifically the present invention is related to those locking systems wherein a door or the like may be securely fastened by means of a mechanical bolt or latch which may be actuated by a removable key. The present invention is directed to a method and apparatus wherein a continuous graphic record may be automatically maintained of the time of use of each of any number of keys of a locking system.

In my co-pending application, Serial No. 84,600, filed January 24, 1961, I have shown and described a locking system in which an electromechanical bolt or latch is controlled by an electronic circuit which is actuated by a key comprising at least one electronic circuit element of a specific value. In a preferred embodiment, an electronic component of a specific value is molded into a removable key assembly. By means of suitable connectors, the key component may be temporarily connected into an oscillator circuit so that a specific frequency signal is generated. A resonant reed relay, turned to the specific frequency, actuates the control circuit which releases the door latch or bolt. Additional contacts in the key assembly are bridged so that the control circuits, such as the oscillator, are powered only when the key assembly is plugged into the key receptacle. My co-pending application describes a method and apparatus for locking doors or the like in which the bolt controlling mechanism is not susceptible to picking or tampering by virtue of its physical construction and its location relative to the key receptacle. The locking system employs a removable key which is almost impossible to duplicate without destroying the original key. All of the keys for a particular locking system contain identical components. Any one of the keys can be used by anyone to open the door. The apparatus is described as a secure locking system but it still retains an inherent weakness in that, once the keys are issued to various persons, there is no way of knowing when, by whom, and how often, the keys are used.

In accordance with my present invention a similar locking system is employed in which each individual key of a locking system has at least one electronic component unique to itself. The use of each key is detectable by suitable discriminating apparatus built into the locking system. Means are provided for recording when each key is used. In a preferred embodiment of the present invention, a multichannel graphic recorder maintains a continuous and automatic record of the use of each key. When a person enters a locked area, the recording channel which corresponds to his particular key is energized. The same recording channing is de-energized when the same key is used to leave the locked area. Since the time base of the graphic recorder is normally synchronized with clock time, a complete record is maintained showing the exact periods of time each key holder spends inside the locked area.

In most locks (a door is held in a closed position by means of a bolt secured by a mechanism which is releasable by means of a key.

An outstanding objection to the locking systems used in the past has been the ease with which keys could be duplicated or loaned to others for nefarious purposes without the original key holder being held responsible.

Another important objection to the locking systems used in the past has been the vulnerability of the bolt controlling mechanism to picking or tampering by burglars and the like.

Another objection to the locking system used in the past was the impossibility of knowing when and how often the keys were being used by those persons to whom they were assigned. Buildings have been unlocked by authorized persons during unauthorized periods of time such as during the night or over weekends or holidays.

The present invention provides a recording secure locking system which is devoid of the above mentioned disadvantages and which at the same time is economical and practical.

An object of my invention is to provide a recording lock and key system in which the key is extremely difficult to duplicate without destroying the original key.

Another object of the present invention is to provide a recording secure locking system in which the person to whom the key was originally assigned is always accountable for the use of the key or any duplicates thereof.

A further object of the present invention is to provide a lock and key system in which the bolt controlling mechanism is not susceptible to picking or tampering by virtue of its physical construction and its physical location relative to the key receptacle.

Still another object of the present invention is to provide a secure locking system in which a continouous graphic record is maintained showing the time of use of each individual key. The individual key record may be activated when the key is used to enter the locked area and de-activated when used to leave the locked area. All periods of time inside the locked area are thus automatically recorded for each key holder.

Other objects and advantages will become more apparent form a study of the following specifications and drawings in which:

FIGURE 1 is a schematic drawing and block diagram showing the method and apparatus of my invention. The relative organization between the key receptacle, control circuits, electromechanical latch, event recorder, and the locked door is shown.

FIGURE 2 shows one kind of key according to my invention in which the electronic components are a capacitor and a resistor each having some preselected specific value.

FIGURE 3 shows the relationship between the specific value of the capacitor component in the key and the control frequency of the locking system shown in FIGURE 1.

FIGURE 4 shows the relationship between specific resistance value and oscillator frequency for the various keys usable with the locking system shown in FIGURE 1.

FIGURE 5 shows a more practical recording lock system according to my invention including a component key, key receptacle, door latch control circuits, specific key discriminator, event recorder, and solenoid door latch.

FIGURE 6 shows a recording secure locking system according to my invention showing a key assembly having three electronic components, separate key receptacles for inside and outside the locked area, dual oscillators for specific key detection, door latch control oscillator, solenoid door latch, door interlock switch, latching relay assembly, and event recorder for recording time periods within the locked area for each key holder.

FIGURE 7 shows the relationships between the values of the three electronic components in the key of FIGURE 6 to the frequencies of the three oscillators which they control. Key component combinations are shown for twenty-five different keys.

FIGURE 8 shows the resonant frequencies of the various reeds of the three reed relays shown in FIGURE 6.

Referring again to FIGURE 1, a door **1** is shown conventionally mounted in the wall **2**. An electromechanical latch **4** restrains the door in a closed position by

means of the bolt 3. The electromechanical latch 4 is similar to a conventional solenoid and the bolt 3 may be either an extension of the movable solenoid core or else connected to it by means of a mechanical linkage. When the electromechanical latch 4 is energized by means of the relay 5, the bolt 3 is withdrawn so that the door 1 may be opened. Mounted on the wall 2 adjacent to the door 1 is an electrical receptacle 11 having electrical contacts 12 which are electrically connected to the oscillators 7 and 8. The output of the oscillator 7 goes to the resonant reed relay 6 and the output of the oscillator 8 goes to the resonant relay 9. When the oscillator 7 operates at the resonant frequency of the reed relay 6, the control relay 5 is actuated thereby allowing the door 1 to be opened. The electrical receptacle 11 serves as the key receptacle according to my invention. A key 17 such as shown in FIGURE 2 comprises at least one electronic component or circuit element which is integral with an electrical connector which matches the key receptacle 11. Similar connectors are commonly used with printed circuits and are well known in the art. A capacitor 18 is shown molded into a plastic rectangular block 17 with its terminals attached to the exposed contacts of the key. The object in FIGURE 2 may be described as a component key because it contains one or more electrical components of a specific or "key" value. The particular component shown in FIGURE 2 which controls the door latch 4 is a capacitor but other components or circuit elements could be used instead or in combination. The component key 17 fits into the key receptacle 11 so that the contacts of the key assembly 17 match with corresponding contacts in the key receptacle 11. When the key 17 is inserted into the receptacle 11 the capacitor 18 is connected into the circuit of the oscillator 7 in such a way that the frequency of the oscillator 7 is determined by the capacitance of the capacitor 18. It can be seen that only keys containing capacitors of one specific value can be used to open the door 1 of FIGURE 1. In a similar manner the resistor 19 in the component key 17 is used to control the frequency of the oscillator 8 when the key 17 is inserted into the key receptacle 11. The signal from the oscillator 8 goes to a resonant reed relay 9 having multiple reeds and corresponding contacts. As an example the reed relay 9 is shown with five resonant reeds each capable of being actuated by a specific frequency from the oscillator 8. When the resonant reed number four of the reed relay 9 is actuated by the specific frequency from the oscillator 8 resulting from the specific value of the resistor 19, the latching relay 10 is closed thereby initiating a recording trace 16 for channel number four of the graphic recorder 15. The graphic recorder 15 is of the type commonly known as an event recorder and they are commercially available having from one to fifty recording channels. Each channel of the graphic recorder 15 can indicate either an on or off condition by the presence or absence of a trace line. Note that the record shown on the recorder 15 of FIGURE 1 shows that key number four 17 was used to leave the locked area at 3:30 and was used again to enter the locked area at 4:15. It can be seen that the holder of key number four is still inside the locked area. The latching relay 10 is a type of relay also commercially available. It has two stable contact positions and when energized will switch from one to the other and remain there indefinitely until energized again. Only key number four is shown for the locking system of FIGURE 1 for purposes of illustration. For this particular locking system there would be five keys similar to the one shown in FIGURE 2. All would resemble the component key 17 and would have a capacitor identical with the capacitor 18 so that each would produce the same frequency when connected into the oscillator 7. Therefore any one of the keys could open the door 1. However, each key would differ in the value of the resistor corresponding to the resistor 19 in FIGURE 2. That is, each key, numbered one through five would contain a resistor (such as the resistor 19) which would result in a different frequency in the oscillator 8 when connected into the key receptacle 11. Each of these five specific frequencies corresponds to the resonant frequency of one of the five reeds of the resonant reed relay 9. Each of the reeds of the reed relay 9, when energized by the proper frequency signal from the oscillator 8, actuates a separate latching relay. One such latching relay 10 is shown which is controlled by the output 13 of reed number four of the reed relay 9. For purposes of simplicity, only one of the five required latching relays is shown in FIGURE 1.

FIGURE 2 shows the details of component key number four. An identification number four 20 is shown to distinguish the key assembly 17 from the four other keys which would be used in the locking system of FIGURE 1. In a preferred embodiment the component key 17 of FIGURE 2 would consist of the capacitor 18 and the resistor 19, each having a specific, pre-selected value, molded into an opaque plastic body with their respective terminals connected to the exposed contacts of a contact assembly which matches the key receptacle 11 contacts 12. For each of the five keys usable with the locking system of FIGURE 1, the resistor 19 would have a different value as described earlier.

FIGURE 3 graphically shows the relationship between the capacitance of the capacitor 18 in a typical key 17 to the resulting frequency of the oscillator 7. The plot 23 shows the relationship. It can be seen that when the key capacitance is of the critical value 113, the oscillator frequency is of the critical frequency 114 which corresponds to the resonant frequency of the reed of the reed relay 6. It can be seen that only keys having a capacitor of the critical value 113 are capable of causing the critical frequency 114 which can actuate the resonant reed of the relay 6, thereby unlocking the door 1.

FIGURE 4 shows graphically the relationship 25 between the resistance of the resistors in the key assemblies and the resulting frequencies of the oscillator 8 of FIGURE 1. It can be seen that five specific critical resistance values can produce five different critical frequencies. For example the specific key resistance value 116 of the resistor 19 in the key 17 causes a specific critical frequency 115 in the oscillator 8 which corresponds to the resonant frequency of reed number four of the reed relay 9. In a similar manner it can be seen that the other specific resistance values correspond to other specific reeds of the reed relay 9.

FIGURE 5 shows in more detail another locking system according to my invention. The key 29 represents key number two of the five keys usable with the locking system of FIGURE 5. Two conventional transistorized phase shift oscillators are shown. In the first oscillator consisting of the transistor 39 and associated components, the frequency is determined by the values of the three capacitors and three resistors in the collector to base feedback loop 27—38. It can be seen that one of the capacitors 32 is connectable between 37 and 38 only when the component key 29 is inserted into the key receptacle 30. Since the other two capacitors and the three resistors in the feedback loop 37—38 are fixed into the circuit, the frequency of oscillation is determined by the value of the connectable capacitor 32. The specific value of the capacitor 32 therefor controls the frequency of oscillation of the transistor 39 when the key 29 is inserted into the key receptacle 30. Signals from the transistor 39 are amplified by the transistor 40. The amplified signals drive the coil 41 of a resonant reed relay having a reed 42 with associated fixed contact 43. When the coil 41 is energized by the proper frequency, the reed 42 will vibrate through a wide arc at its resonant frequency thereby intermittently touching the fixed contact 43. When the reed 42 and the contact

43 are intermittently connected, the control relay coil 44 is energized. The resistor and capacitor across the relay coil 44 eliminate chattering of the relay contacts 45 due to the intermittent nature of the reed relay contact closure. When the control relay coil 44 is energized, the contacts 45 are closed and the solenoid latch 46 is energized thereby drawing the bolt 47 which releases the door 48. It can be seen that when a component key such as the key 29 is inserted into the key receptacle 30, the door 48 will be unlocked only when the capacitor 32 is of one specific, critical and preselected value. Similar keys having capacitors of different values cannot open the door. In the second transistorized oscillator of FIGURE 5, consisting of the transistor 49 and associated components, the frequency is similarly determined by the three capacitors and the three resistors in the collector to base feedback loop 51. One of the critical resistors 33 used to establish the oscillator frequency is connectable between the lead 51 and the ground lead 117 only when the component key 29 is inserted into the key receptacle 30. The specific value of the resistor 33 in the component key assembly 29 thus determines the exact frequency of the transistor 49. Signals from the transistor 49 are amplified by the transistor 50. The amplified signals drive the coil 52 of the reed relay having five resonant reeds and five associated fixed contacts. For example when the reed 53 is driven at its resonant frequency by the coil 52, intermittent contact is made with the fixed contact connected to the lead 54. The resonant reed 53 is considered as reed number two and its resonant frequency corresponds to the oscillator frequency which is caused by the specific resistance of the resistor 33 of the key 29 which is key number two. The numeral two 34 identifies key number two. When reed 53 number two is actuated by the insertion of key number two, the fixed contact connected to the lead 54 is contacted thereby closing the control latching relay 55. As before, the resistor-capacitor across the coil of the latching relay 55 is used to prevent chattering due to the intermittent nature of the resonant reed contact closure. Thus reed 53 and contact number two of the resonant reed relay control the latching relay 55 which is considered as latching relay number two. When the contacts 56 of the latching relay 55 are closed, trace 59 of the graphic recorder 58 is energized so that a time record is maintained until the latching relay 55 is again energized so that it latches into its open contact position. Although the latching mechanism is not shown, the contacts 56 have two stable positions, one open and one closed and the coil need not be kept energized to maintain either position. Whatever the position of the contacts, when the coil is reenergized the contacts latch over to a new position. In a similar manner, the other four reeds and contacts of the reed relay can control four other latching relays which regulate the other four recording channels of the graphic recorder 58. It can be seen from the trace 59 of the graphic recorder 58 that the holder of key number two has been inside the locked area since 7:30. Since the holder of key number two is inside the locked area, the next time his key is used it will be to get outside. When the latching relay number two is actuated again by the insertion of key number two, the contacts 56 are transferred to the non-recording position. It is assumed that identical key receptacles exist with connections in parallel, one outside and one inside the locked area. The recording system of FIGURE 5 has the obvious disadvantage in that if the "in and out" sequence were disrupted for some reason, the corresponding record on the recorder 58 would be thereafter reversed. This disadvantage is easily remedied by wiring the inside and outside key receptacles differently. This may be done in such a way that the outside receptacle can only be effective in switching individual key records into the "in" position and the inside receptacle can only be effective in switching the individual key records into the "out" position. FIGURE 6 shows one method of achieving what was just described. The individual key holder can only use the outside receptacle when the graphic recorder indicates that he is "out."

A very important feature of the locking system according to my invention is shown in FIGURE 5. When the component key 29 is inserted into the key receptacle 30, the shunt 28 between two of the contacts of the key assembly allows the ground side of the various electronic circuits to be connected to the positive side of the battery 60. Thus no circuits are energized except during the brief periods when a suitable key is inserted in the key receptacle. The key 29 then serves to turn the control circuits on and to regulate their frequency thereby causing the two separate switching functions to take place, namely, the unlocking of the door 48 and the transfer of the individual key recorder trace 59.

FIGURE 6 shows a locking system according to my invention which will simultaneously record the "in" or "out" status of twenty-five different key holders. The key receptacle inside the locked area is wired slightly different from the key receptacle outside the locked area so that the possibility of confusion in the individual "in-out" recording system is eliminated. A remotely operated switch is provided so that the door latch may be opened by a receptionist or the like. A door interlock is provided so that the latch bolt always remains withdrawn when the door is open.

The component key assembly 71 in FIGURE 6 shows, in plan diagram, the contact and component arrangement of key number eight of the twenty-five keys usable with the locking system shown for the outside key receptacle 76 and the inside key receptacle 77. Contacts shown along the left side of the key 71 correspond to the contacts along the left sides of both of the key receptacles 76 and 77. The contacts of the top three pairs of the inside and outside key receptacles are wired in parallel. The right contacts of the bottom pair are also wired in parallel. The only contact which is wired differently, when comparing the inside and outside key receptacles, is the left contact of the bottom pair, namely, the contact 123 of the outside key receptacle and the contact 79 of the inside key receptacle. Current through these contacts actuates the latching relays through one set of their own contacts 124 so that only the correct key in the outside receptacle can start the "in" trace 108 of the graphic recorder 107. In a similar manner only the correct key in the inside receptacle can stop the "in" trace 108 of the recorder 107. The graphic recorder, also known as an event recorder, has twenty-five fixed styli such as the stylus 109 which produces the trace 108 for key holder number eight. When circuits to these styli are closed, a trace is recorded. When circuits to the styli are open, no trace is recorded. The contacts 101 of the latching relay are closed so that the stylus 109 is recording a trace 108. Key holder number eight therefore is inside the building. The second set of contacts 124 of the latching relay are mechanically coupled to the contacts 101 so that when the contacts 101 are recording the key holder number eight as inside the building, as in FIGURE 6, only current from the inside key receptacle is available to the negative side of the latching relay coil 100.

The capacitor 72 in the component key assembly 71 controls the frequency of the oscillator 63 when the key assembly is inserted into either key receptacle. All twenty-five keys of the locking system of FIGURE 6 have capacitors of an identical but very specific value. The capacitor 72 has a critical capacitance value which causes the oscillator 63 to oscillate at exactly the resonant frequency of the reed 64 of the reed relay 120. Thus when any one of the twenty-five keys are inserted into either receptacle, the resonant reed contacts 64 will close intermittently, and the control relay coil 65 is energized thereby closing the contacts 66. Contact chatter is elim-

inated by the resistor-capacitor 119. The contacts 66 are thus closed when any one of the twenty-five component keys (such as the component key 71) is inserted into either of the key receptacles.

The contacts 66 alone cannot actuate the solenoid latch 68 however. Current for the operation of the solenoid latch is only provided when the contacts 90 of the individual control relay 89 are closed. The contacts 90 are in series with right pair of the contacts 66. Therefore the solenoid latch 68 is actuated only when the contacts 66 of the control relay 65 and the contacts 90 of the individual control relay 89 are both closed. The individual control and latching relay assembly 106 consists of a ordinary type relay 89 having double pole, normally open contacts 90 and 91, and a latching relay coil 100 and associated parts including the double pole double throw contacts 101 and 124. There are twenty-five individual control and latching relay assemblies required for the locking system of FIGURE 6; one for each individual key holder. The individual control and latching relay assembly 106 may be described as individual relay assembly number eight and the individual control relay 89 will only be actuated when component key number eight is inserted into either of the key receptacles.

The resistors 73 and 74 in the component key assembly 71 control the frequencies of the oscillators 84 and 92 respectively. Each individual key of the twenty-five keys usable in this locking system has its own combination of two resistors each of which has some preselected specific value. In the key 71 the resistor 73 may be called resistor one and it controls the frequency of oscillator B84. The oscillator 84 drives the coil 85 of resonant reed relay B which has five resonant reeds and associated fixed contacts. Each of the five resonant reeds of reed relay B responds to a specific frequency of the oscillator B. Therefore five different specific resistance values may be used for resistance one of the key assemblies. Since there must be twenty-five keys, there should be five resistors of each of the five specific values from which resistor one can be selected for each key assembly. Out of the twenty-five component keys for the locking system of FIGURE 6 there will be five keys which can cause the actuation of each of the five reeds of the reed relay B. That is, each reed can be actuated by any one of five different keys, namely the five which have identical resistor one values which produce the critical frequency in the oscillator B which corresponds to the resonant frequency of that particular reed. When any one of the reeds of the reed relay B is intermittently closed with its corresponding fixed contact, the positive side 87 of the coil of the individual control relay 89 is energized. However, the negative side 95 of the relay coil 89 must also be simultaneously energized before the contacts 90 and 91 will close.

The resistor 74 in the component key assembly 71 of FIGURE 6 controls the frequency of oscillator C92 in precisely the same way that resistor 73 controls the frequency of oscillator B84. The resistor 74 may be called resistor two and its value determines the frequency of oscillator C. Oscillator C92 drives a reed relay 93 having five reeds with five different resonant frequencies and five corresponding fixed contacts. Thus five different specific resistance values may be used in the key assemblies for resistor two. Each of these five specific resistance values can produce a specific frequency in the oscillator C92 which corresponds to the resonant frequency of one of the reeds of resonant reed relay C. Since only five different resistance values may be used for resistor two (such as the resistor 74) in the component key assemblies, there will be five separate keys which have each of the five resistance values. Thus there will be five keys which can actuate each one of the reeds of the reed relay 93. The contacts of the reed relay C, such as the reed 94 and the fixed contact connected to 97, when vibrated at their resonant frequency, can switch current from the negative side of the battery to the negative side 95 of the coil of the individual control relay 89. One side of the individual relay coil 89 is energized by the contacts of reed relay B and the other side of the coil 89 is powered by the contacts of the reed relay C. There are twenty-five different individual control and latching relay assemblies, such as the assembly 106. The control relay coil of each assembly (such as the relay coil 89) is actuated by a combination of any one of the five switching contacts from both reed relay B and reed relay C. The negative side of each of the twenty-five control relay coils (such as the relay coil 89) must be energized through one of the reed contacts of the reed relay C and the positive side of each of the twenty-five control relay coils must be energized through one of the reed contacts of the reed relay B. It can be readily seen that twenty-five such combinations are possible between two reed relays each of which has five reeds and contacts.

Each of the twenty-five component keys for the locking system of FIGURE 6 must have a capacitor of one specific value which is the same for all keys. This capacitor causes the closure of the contacts 66 of the control relay 65 when the key is inserted in either key receptacle 76 or 77.

The relatively complex apparatus of FIGURE 6 is described mainly to show how a large number of individual discriminating and control functions can be obtained with only a few reed relays by using various reed combinations of two multiple reed relays. Obviously, in the same manner, one hundred individual discriminating functions could be obtained from two resonant reed relays each having ten reeds. For most applications, however, it is preferably to have a separate resonant reed for each individual key. For example, a typical recording locking system would consist of ten individual keys each having a component of a different value. The associated control and discriminating system would include a resonant reed relay having ten reeds, each one responsive to only one of the ten keys. Each reed would control one of the ten individual recording channels of an event recorder. A separate control circuit can be used to unlock the door or else the output from any one of the ten reeds can be used to control the door latch mechanism. To distinguish between the door locking system, which has been described in my earlier patent application, and the individual key sensing and recording system of the present invention, all of the apparatus shown in the figures show separate key components and control circuits for performing the two distinct functions of door lock control and individual key sensing and recording. Obviously if the individual key sensing system identifies the key as one belonging to the series for that locking system it might as well also unlock the door.

A switch 70 is provided for remotely controlling the solenoid latch 68 thereby withdrawing the bolt 61 and releasing the door 62. This switch may be used by a receptionist or the like for the convenience of visitors without keys upon presentation of proper identification or credentials. The interlock switch 117 is controlled by the position of the door 62. When the door 62 is in the open position, the contacts of the interlock switch 117 are closed. When a proper key is in the key receptacle, the relay 65 will be actuated and the contacts 66 will be closed. The solenoid latch 68 may then remain in the withdrawn position, even if the key is removed from the receptacle, until the door is closed. If the proper key is not in the key receptacle the solenoid latch 68 cannot be actuated by tampering with the interlock switch 117. A buzzer 69 or the audible signal is sounded for the periods during which the door is unlocked.

The shunt 83 between the third pair of contacts of the key 71 is used to switch the ground side of the various electronic circuits when the key 71 is inserted into either key receptacles 76 or 77. When the key 71 is inserted

into either key receptacle, the contact 82, which is connected to the positive side of the battery, is connected to the opposite contact 81 through the shunt 83 in the key. The positive side of all of the circuits are powered from the contact 81 as indicated in FIGURE 6.

FIGURE 7 shows the key component values for all twenty-five of the keys usable in the recording locking system of FIGURE 6. With the key numbers from one to twenty-five are shown the corresponding values of the capacitor (such as the capacitor 72), resistor one (such as the resistor 73), and resistor two (such as the resistor 74). For each key number, the resulting frequencies for all three oscillators are also shown.

FIGURE 8 shows the resonant frequencies for the various reeds of the three resonant reed relays shown in FIGURE 6.

Referring again to FIGURE 6, the capacitor 72 of the component key number eight 71 has the value of .06 microfarad. The resistor 73 has the value of 9.5 thousand ohms. The resistor 74 has the value of 4.8 thousand ohms. The values may be obtained from the table 127 in FIGURE 7. When the key 71 is inserted into either key receptacle 76 or 77, all electronic circuits are connected to the positive side of the power supply by means of the key shunt 83. The capacitor 72 causes oscillator A63 to oscillate at a frequency of 346.6 cycles per second. The resistor 73 causes the oscillator B84 to oscillate at 212.6 cycles per second. The resistor 74 causes the oscillator C92 to oscillate at 416.3 cycles per second. From FIGURE 8 it can be seen that the resonant frequency of the reed 64 of reed relay A120 is 346.6 cycles per second. The resonant frequency of reed number two 86 of reed relay B85 is 212.6 cycles per second. The resonant frequency of reed number three 94 of reed relay C93 is 416.3 cycles per second. Therefore when the key 71 is inserted into either key receptacle 76 or 77, the various resonant reed contacts are vibrated at their resonant frequency by the various oscillators. As a result the control relay 65 is energized and the individual control relay 89 is energized from both sides of the coil. The solenoid latch 68 is actuated, the bolt 61 is withdrawn, and the door 62 may be opened. Depending upon whether the inside receptacle 77 or the outside receptacle 76 is used, the individual latching relay, consisting of the coil 100, contacts 101 and 124 and other associated parts, switches the event recording channel number eight to the proper recording condition. If the outside receptacle 76 is used, the recording trace 108 will be initiated by the latching relay contacts 101 through the recording stylus 109 thereby showing that the holder of key number eight 71 has entered the locked area. When the holder of key number eight 71 uses the inside key receptacle 77 to leave the locked area, the recording trace 108 is interrupted by the contacts 101.

Any one of the twenty-five keys may be used to open the door in a similar manner. The recorder 107 maintains a continuous record which shows when each of the twenty-five key holders are inside or outside the locked area.

Any electronic circuit element can be used as a key component according to my invention providing it is capable of controlling or otherwise modifying the flow of electrons in the associated control circuit. Capacitors and resistors have been found to be very satisfactory key components. In these specifications and drawings of my invention I have selected an oscillator as a preferred type of control circuit. The frequency of the oscillator is determined by the specific value of one or more of the components in the removable key assembly. A resonant reed relay is shown as the preferred frequency discriminator used to detect specific oscillator frequencies. The resonant reed relay is highly selective and stable and can perform simultaneous switching and discriminating functions. An obvious alternative to this preferred form of my invention would be to use one or more electronic circuit elements having specific values in the key and to have the control circuit respond to a direct measurement of the key component values. This could be done most easily with the usual bridge circuits which are commonly used to measure either resistance, capacitance, or inductance.

The component key of my invention can be made in a variety of physical shapes and sizes. A simple rectangular block two inches high, one inch wide, and three-eighths inch thick has proven to be a convenient size. At least one electronic component must be included in the key and this has been cast into a block of opaque epoxy resin with the leads attached to the contacts of a male printed circuit connector which protrude from one edge of the plastic block. The electronic component is protected from moisture and other damage by being cast into a block of plastic. The opaque plastic also serves to conceal the nature of the key components from those who would attempt to duplicate the key. The component key receptacle, which is mounted on or near the door, can consist of a female printed circuit connector which matches the key connector. In a preferred form of my invention, two of the contacts of the key are shorted as described and shown in the specifications and drawings so that the electronic control circuits are powered only when the component key is inserted in the key receptacle.

Each locking system according to my invention would consist of a series of key assemblies any one of which is capable of unlocking the door. Each individual key has one or more electronic components which differ in value from all of the other keys of that particular series. Means must be provided in the control and recording system for distinguishing each individual key from all the others so that a graphic record can be maintained which shows the time when each key is used. In a preferred embodiment, the inside and outside key receptacles are wired somewhat differently from each other so that the recording system may be used to differentiate between key insertions for leaving and for entering the locked area. The key receptacles may be situated either on the door itself or preferably on the wall adjacent to the door. Any number of solenoid latches can be controlled by the control relay. Where a high degree of security is maintained, it might be desirable to have several electromechanically controlled bolts on a single door all of which can be actuated and drawn by the insertion of the proper key.

In all of the drawings of the present patent application, a separate discriminating and control system is shown for performinng the two distinct functions of lock control and individual key sensing-recording. This has been done to distinguish between the door locking system, which has been described in my earlier co-pending patent application, and the individual key sensing and recording system of the present invention. It can be readily seen in FIGURE 1, however, that the output from any one of the individual reeds of the reed relay 9 can also be used to actuate the relay 5 which controls the electromechanical latch 4. Thus the individual key sensing and lock controlling circuits may be combined so that both functions are performed by the same discriminating and control system.

As can be seen from the foregoing specifications and drawings, I have provided a method and apparatus wherein a continuous graphic record may be automatically maintained of the time of use of each of any number of keys of a locking system. A locking system is used in which an electromechanical bolt or latch is controlled by an electronic circuit which is actuated by a removable key comprising at least one electronic circuit element of a specific value. The locking system has been described fully in my earlier co-pending patent application. In the present invention each individual key of a locking system has at least one electronic component unique to itself. The use of each key is detectable by suitable discriminating apparatus built into the

locking system. Means are provided for recording when each key is used. In a preferred embodiment, a multi-channel graphic recorder maintains a continuous and automatic record of the use of each key. When a person uses a key to enter the locked area the recording channel which corresponds to his particular key is energized. The same recording channel is de-energized when the same key is used to leave the locked area. The time base of the graphic recorder corresponds to clock time so that a complete record is maintained showing the exact periods of time each key holder spends inside the locked area.

In the recording locking system herein described, the person to whom the key was originally assigned is always accountable for the use of the key or any duplicates thereof. If the key is lost and the loss is reported, the locking system can be easily changed so that the lost key will no longer open the door. This can be done without replacing the locking system but merely by making a minor adjustment. A new key can then be issued to replace the lost one.

The graphic record which shows the periods of time each individual key holder is inside the locked area also serves as a time clock to indicate late arrivals and early leavers. This is particularly valuable for junior executimes and the like who would object to the conventional time clock. The graphic record would, of course, show the length of all lunch periods, all departures from work during working hours, all overtime work, and all evening and weekend work. Besides the obvious security advantages, the graphic work time record for each employee might serve as one basis for judging the employees diligence when considering him for promotion.

It should be understood that the foregoing description of this invention concerns only the preferred embodiments thereof and that accordingly changes and modifications may be made therein by those skilled in the art without departing from the spirit and scope of the invention as defined in the following claims.

Having thus fully described my invention, I claim:

1. A recording locking system of the character described comprising in combination: a removable key assembly having at least one electronic component of a specific value; a first electrical contact assembly integral with said key to which the said electronic component is connected; an outside key receptacle comprising a second electrical contact assembly into which the said first electrical contact assembly may be inserted, the said outside key receptacle being mounted conveniently adjacent a latchable door outside a locked area; an inside key receptacle comprising a third electrical contact assembly into which the said first electrical contact assembly may be inserted, the said inside key receptacle being mounted conveniently adjacent the said latchable door inside the said locked area; an electrical discriminating control circuit responsive to electronic components of the type and specific value as the said component in the key assembly, the input of the said discriminating control circuit being connectable to the said key electronic component through the said second or third electrical contact assemblies when the said key assembly is inserted in either the outside or inside key receptacles; electrical switching means responsive to the said electrical discriminating control circuit; electromechanical latching means actuated in response to the closure of said electrical switching means; means for securing the aforementioned door in a closed position with the said electromechanical latching means until the said removable key assembly is inserted into one of the said key receptacles; graphic recording means having a switchable trace record and a continuous time base; means for initiating the said trace record when the said key assembly is inserted into the said outside key receptacle; and means for interrupting the said trace record when the said key assembly is inserted into the said inside key receptacle.

2. In a locking system of the type wherein a door or the like is secured by a latching mechanism releasable by means of an electronic control circuit which is actuated by the temporary connection of a key assembly having at least one electronic component of a specific value, apparatus for recording the use of the said key assembly which comprises: a graphic recorder having at least two recording conditions for maintaining a continuous time record; means for causing the said graphic recorder to assume the first of the said two recording conditions upon the temporary connection of the said key assembly to the said control circuit from outside the said secured door; and means for causing the said graphic recorder to assume the second of the said two recording conditions upon the temporary connection of the said key assembly to the said control circuit from inside the said secured door, a continuous record being thereby maintained of the periods of time the holder of the said key assembly spends inside the said secured door.

3. In a recording lock system of the character described, the apparatus which comprises: a series of removable key assemblies, each having at least one electronic component of a different specific value; an electronic oscillator circuit, the frequency of which may be determined by any one of the said electronic components; means for connecting any one of the said electronic components into the said oscillator circuit, each thereby producing a different frequency; a series of frequency discriminating means each responsive to only one of the frequencies produced by the said oscillator; a series of switching means each responsive to the output of one of the said frequency discriminators, each of the said switching means being thereby actuated whenever signals of the corresponding specific frequency are produced by the said oscillator; a multi-channel graphic recorder, each channel of which can record, as a function of time, at least two operating modes, there being one recording channel connected to each one of the said series of switching means; and means for transferring the operating mode of each channel of the said recorder in response to the actuation of each of the corresponding said switching means, a graphic record being thereby maintained of each use of the said series of removable key assemblies as a function of time.

4. In a recording lock system of the character described, the apparatus which comprises: a series of removable key assemblies, each having at least one electronic component of a different specific value; an electronic oscillator circuit, the frequency of which may be determined by any one of the said specific valued components; means for connecting any one of the said electronic components into the said oscillator circuit, a different specific oscillator frequency thereby resulting from the use of each of the said key assemblies; a series of resonant reed relays, each having contacts which close only in response to one of the said specific frequencies from the said oscillator; separate power switching means effected through the actuating of each of the said resonant reed relays, the said power switching means being thereby actuated whenever signals of the corresponding specific frequency are produced by the said oscillator; and a multi-channel event recorder having a separate channel actuated by each of the said power switching means, a graphic record being thereby maintained of each use of the said series of removable key assemblies as a function of time.

5. In a recording lock-system of the character described, the apparatus which comprises: a series of removable key assemblies, each having at least one electronic component of a different specific value and each having at least a pair of electrical contacts to which the terminals of the said components are connected; a key receptacle comprising an electrical contact assembly into which the contacts of any one of the said removable key assemblies may be inserted, the said key receptacle being mounted conveniently near a latchable door; an elec-

tronic oscillator circuit the frequency of which may be determined by the specific value of any one of the said electronic components when the corresponding key assembly is inserted into the said key receptacle, a different specific oscillator frequency thereby resulting from the insertion of each of the said key assemblies; a series of resonant reed relays, the contacts of each closing only in response to signals of one of the said specific frequencies from the said oscillator; and a multi-channel event recorder having a separate channel actuated by each of the said resonant reed relay contacts, an event mark being thereby made on the proper channel as each of the said key assemblies is used as a function of time.

6. In a locking system of the character described, the lock recording system which comprises: an electromechanical latch for securing a door or the like; power switching means for releasing said latch; a series of key assemblies each of which embodies at least one electronic component of a different specific value; a series of electronic control circuits each of which is responsive to only one of the said electronic components; means for temporarily connecting the electronic component of any one of the said key assemblies into the common input of the said series of control circuits, each key assembly being capable of actuating only one of the said control circuits; means for actuating the said power switching means upon actuation of any one of the said control circuits, the said latch being thereby releasable and the said door being thereby openable; and a multiple channel event recorder, each channel of which is responsive to only one of the said control circuits, each channel thereby corresponding to one specific key assembly, a continuous record of the time of use of each of the series of key assemblies being thereby maintained as a function of time.

7. In a locking system of the type wherein a door or the like is secured by a latching mechanism releasable by means of an electronic circuit which is actuated by the temporary connection of one of a series of removable key assemblies each having at least one electronic component of a specific value, apparatus for recording the use of each key which comprises: a series of key assemblies each having an electronic component of a different specific value, each key assembly being thereby unique while at the same time retaining the ability to effectuate the release of the aforementioned latching mechanism; a series of electronic control circuits each of which is responsive to only one key assembly of the said series of key assemblies; means for temporarily connecting any one of the said series of key assemblies into the common inputs of the said series of control circuits; a graphic recorder having a time scale and multiple channels each of which is responsive to only one control circuit of the said series of control circuits, each recording channel thereby corresponding to only on particular key of the said series of key assemblies; means for initiating each individual recording trace of the said graphic recorder in response to the use of each corresponding key assembly from outside the aforementioned secured door; and means for terminating each individual recording trace of the said graphic recorder in response to the use of each corresponding key assembly from inside the aforementioned secured door, a continuous graphic record of the periods of time each individual key holder spends inside the said secured door being thereby maintained as a function of time.

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