DESIGN AND INSTALLATION OF A FIRE ALARM SERVICE SYSTEM FOR AN INDUSTRIAL PLANT

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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Design and installation of a complete fire alarm and
THE DESIGN AND INSTALLATION OF A COMPLETE FIRE ALARM AND NIGHT WATCH SERVICE SYSTEM FOR AN INDUSTRIAL PLANT

A THESIS

PRESENTED BY

LOUIS HERMAN ROLLER

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

ELECTRICAL ENGINEER

MAY 29, 1918

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LETTER OF TRANSMITTAL.

May, 1913.

To the President and Faculty
of Armour Institute of Technology.

Gentlemen:

I have the pleasure to submit herewith a thesis, entitled "The Design and Installation of a Complete Fire Alarm and Night Watch Service System for an Industrial Plant", in conjunction with my application for the degree of Electrical Engineer.

The thesis is a description of an installation in a large manufacturing plant, the name of which is withheld because of the importance of the installation at the present time in the protective system of the plant.

The part which the writer had in the work was in the original design and development of the special features of the system which were necessary to adapt it to the peculiar needs of this particular plant, in the design and arrangement of the central office equipment, and in exercising supervision over the details of construction and installation of the central office equipment. The detail drawings of the equipment are not given in the thesis, but were prepared as part of the work, and were faithfully executed; the system was put into successful operation without any changed of importance being found necessary in the original designs.

Respectfully yours,

[Signature]

28096

L. H. Roller.
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THE DESIGN AND INSTALLATION OF A COMPLETE
FIRE ALARM AND NIGHT WATCH SERVICE SYSTEM
FOR AN INDUSTRIAL PLANT

INTRODUCTION.

One of the important problems which comes within the scope of work of the plant engineer in an industrial concern is that of protection of the property during the hours when the plant is not in operation. Protection is required against losses by fire, theft, and carelessness.

The plant, whose system forms the subject of this thesis, maintains a corps of fire-fighters and is equipped with a modern sprinkler system complete in every respect for protection against fire. It also maintains a police department for protection against theft and dishonesty. Co-operative with both these departments is the night watch service, which furnishes protection against carelessness.

The characteristic feature of this service is that of patrol or guard duty; all parts of the plant are visited once per hour nights, Sundays, and holidays, commencing within one hour after the employees are supposed to leave the plant, and ending when the day police force arrive, which is about one-half hour before employees report for work.

The duties of the night watch service are as
follows, arranged approximately in the order of their importance:

1. Promptly report incipient fires and
2. Do whatever is possible to control such fires until fire department arrives.
3. See that no employees remain in the plant after hours without a pass.
4. Close all windows and fire doors.
5. Turn off lights not in use.
6. Report leaky plumbing fixtures or piping where there is a waste of water or steam.

Requirements of the System.

To assist in the efficient performance of these duties it is necessary that a signalling system be provided which will meet the following requirements:

1. Enable the watchman to send in a fire alarm and give the location of the fire.
2. Enable headquarters to keep in touch with the watchmen and know that they are patrolling their respective routes as required.
3. Enable the watchmen to send in a call for assistance, or report unusual conditions, especially inability to perform duties.
4. Enable headquarters to call watchmen and give special instructions.
5. Enable the fire department when called out to communicate directly with their headquarters, and not depend on the telephone system in the plant, with its exchange delays.
THE OLD SYSTEMS OF FIRE ALARM AND NIGHT WATCH SERVICE.

The old systems, which were in use before the new system was installed, attempted to meet only the first two requirements, namely, to give fire alarms and report watch calls, and each of these functions was performed by a separate and distinct signalling system.

The Old Fire Alarm System.

The old fire alarm system had been installed in connection with the private fire department, and was for the purpose of calling this department out and giving the location of the fire. The box stations throughout the plant were so distributed that every floor of each fire section of the buildings had a fire alarm box, which, when operated, sounded a gong and recorded the box number three times on a pen register at the fire house.

The box stations for this system consisted of an inner and an outer box, the inner box contained a mechanical movement which, when started in operation by pulling lever down and releasing it, opened the alarm circuit the correct number of times and at proper intervals to register the number of the box. The outer box was fitted with a door containing a glass panel, and was so designed that breakage of the glass would allow the door to be opened and the lever on the inner box to be pulled. The outer box also contained
a telegraph key by means of which the alarm circuit could be opened by hand; the key was provided for the use of the fire chief or other official in sending a test call, enabling him to add a long dash after the box number had registered, which signalled the fire department not to answer the call.

The circuit of the old fire alarm system was of the simple series type. The fire house is located in the approximate center of the plant and from it were run several circuits, one in each general direction to include all boxes in that direction. Boxes on the individual circuits were connected in series, and at the fire house the several circuits were connected in series, thus putting each box in series with every other one in the plant. Current from a battery was sent through a sensitive relay in series with the box circuits, so that the operation of any box would affect the relay, which in turn operated a local circuit in which the pen register and fire gong were connected.

The wiring consisted of #14 B & S gauge copper wire, rubber-covered, enclosed in pipe conduit in the buildings. In the tunnels between buildings the circuit consisted of a #14 rubber-insulated pair enclosed in a lead sheath, and where it was necessary to bury a circuit underground, the lead-covered cable was enclosed in conduit. The #14 wire, which is rather large for signalling purposes, was used to keep the resistance of the line as low as possible,
and give a good factor of mechanical strength, which was desirable for reliability of operation.

The apparatus at the fire house was enclosed in a cabinet consisting of a slate shelf and panel with glass doors. On the shelf were the relay, pen register and automatic tape take-up, while on the slate panel were mounted the line cut-outs, battery switch, charging rheostat, voltmeter and milli-ammeter. The line cut-outs were similar to those used in telegraph work, and consisted of brass blocks to which the wires from the several lines connected, and which could be interconnected by means of pin plugs; normally the pin plugs were so arranged that all lines were in series, and in case of open circuit on any line, that line could be cut-out or short-circuited and the other lines continued in operation. The battery switch was in principle a double throw switch arranged to throw one battery to charge while the other was discharging to the line.

The battery, which consisted of nine cells of the lead-acid type and required about twenty-two volts for charging, was charged from the 220-volt direct current power circuit of the plant, and about ninety percent of the energy was wasted in the charging rheostat, which was mounted on a brick wall about five feet from the cabinet so the latter would not be affected by the heat of the rheostat.
The Old Watch Service System.

The old watch service system was that of the A. D. T. Co. The boxes were painted blue to avoid confusion with the red fire alarm boxes of the plant system, and were located according to the routes of the watchmen. They were not as numerous as the fire alarm boxes. Their location was such that the watchman, in pulling the boxes on his route in the proper order, would have to patrol all of the important sections of the route.

Pulling a box was done by means of a key, which, inserted in an opening in the box cover, enabled the watchman to operate the box lever without opening the cover. This box was also designed for fire alarm service, in which case a glass panel in the cover was broken, the cover opened, and the lever pulled. As fire alarm service was not required of the boxes in this place a piece of sheet metal was put in place of the glass to prevent the use of these boxes for fire alarm.

The headquarters for the watch service was at the regular central office of the A. D. T. Co., some three or four miles from the plant. The office served a large number of industrial plants in this territory, and was maintained to give a service in compliance with the requirements of the Board of Fire Underwriters.

The circuit of the A. D. T. system was normally operated as a closed circuit with all boxes
in series, but it was possible to operate it open-circuited with each box in parallel to ground. This system required two line wires with a ground return. The circuit and central office equipment were the same as for the new system, and are shown in Fig. 1.

Limitations of the Old Systems.

The limitations of the old fire alarm and night watch service systems are apparent, the principal one being the inability of communication between watchmen and headquarters. The old fire alarm system was not modern in that trouble in any one box or line would affect the whole system, and an open circuit would render a large number of boxes useless. The segregation of the fire alarm and watch service systems was a source of weakness, since the watchmen were not familiar with the location of the plant fire alarm boxes, and on several occasions used their own call boxes for this purpose, resulting in a delayed alarm, and some confusion on the part of the plant fire department, who were not familiar with the location of the watchmen's box stations.

A. D. T. assistance to watchmen was of little value on account of the distance from central office to the plant, which made it necessary for the office manager to call up the fire or police department whenever a watchman had not been heard from for fifteen minutes, and although he sent out tracers at once to
look for possible trouble, by the time they arrived at the plant the value of their assistance was doubtful. It was further discovered that the reports of the A. D. T. office were not accurate enough to warrant censuring the watchmen for apparent laxity in the performance of their duties.

THE NEW SYSTEM OF FIRE ALARM AND NIGHT WATCH SERVICE.

The requirements of the new system, besides combining the fire alarm and night watch features, were to provide a means of communication between the watchmen and headquarters. It was decided to use the same circuit scheme as the old A. D. T. system, and the license to use the boxes and office equipment was obtained from this company, by whom they were patented. The problem before the engineers then was that of communication and it was decided to install a telephone system with plug jacks at each box and a buzzer to signal the watchman, who carried a telephone handset, the equipment at the central office being especially arranged for this service.

Principle of the New System.

The features of the A. D. T. circuit which commended it for this service were ability to operate with faults in the circuit, under either open or closed circuit conditions, that is, with one or more open circuits in the line and a ground at any point;
and the non-interference feature, which cuts-out one box in case two are pulled at the same time on fire alarm. Further, it was believed that the telephone system could be combined with the fire alarm circuit without the use of additional wires.

Figure 1 shows the circuit diagram of the A. D. T. system with connections for three boxes. Each box contains three contact wheels, two of which have teeth corresponding to the number of the particular box, the third is the shunt contact wheel which is the same in all boxes irrespective of the box number. The contacts forming a connection between points 1 and 2 are those carrying the line current when the system is operating normal under closed circuit conditions. The contact and grounded wheel connecting to post G transmit the box signal when the system is operating grounded with a faulty line under open circuit conditions. The wheel S makes a connection on the line which shunts all boxes beyond the one being operated, thus preventing interference and allowing one box number to be reported in case two boxes are operated at the same instant.

Two relays are used for each circuit as shown; they have contacts so arranged that operation under either open or closed circuit conditions is possible. Under normal conditions with closed circuit one relay is used to operate the pen register which prints the signal on a paper tape, while the other
relay operates a signal lamp which flashes the signal to the operator. There is thus secured a permanent record of the box signals, and also a visual transmission which is often more convenient at the instant for the operator than reference to the register.
The signal lamp performs another service which is perhaps of greater importance, namely, that of indicating trouble on the line and guiding the operator in manipulating the switches M, L, and R to promptly put the circuit into operating condition again.

Description of Operation.

Under normal operating conditions as shown in the diagram, the current from the battery flows through the relay RR, out on L1, through the box contacts and back on L2, through relay LR and switch N to battery. The relays are thus continuously magnetized and their levers are held against the upper contacts, which are out of circuit for normal operation. When a box is operated the current is interrupted to correspond to the box number, and the relay levers make contact with the lower points, transmitting the box number to the local circuit of the register and of the lamp. The switch M is used only in case of trouble on the line, and L and R are cut of circuit unless M is thrown for grounded operation in which case they are manipulated as is dictated by the nature of the fault.

The value of the circuit connections in case
of trouble on the line is best shown by assuming the two most common faults, open-circuit and ground, and noting the effect on the circuit, which is shown for normal operation in the diagram. In the case of an open circuit anywhere on the line or in the boxes the levers of both relays will drop, making contact with the lower points, causing the lamp to light and the register to run continuously. The operator then throws switch M into other position, which changes the relay connections from series to parallel, and cuts out the lamp circuit, causing the local contacts of both relays to operate the register. Then RR will relay only signals from boxes between it and the open, and LR will relay signals from the remaining boxes, which will be between it and the open. It will be seen that the circuit is thus divided into two parts, each a complete circuit with ground return for each of the boxes, which are now in parallel. By noting which of the box numbers register on each relay, the trouble man can get location of the fault between two boxes before leaving the relay board. The operator will know when the open has been repaired, for both relays will respond at the same time to any box on the line; he can then throw switch M back to position for normal operation.

In case of a ground at any point on the line or in the boxes during normal operation, the relay LR will be shunted by the ground, its lever will drop,
and cause the lamp to light. The relay RR will not be affected except that the current in its coils will be increased, and all signals transmitted by boxes between RR and the ground will be registered, while those boxes between LR and ground will be shunted and their signals will not register. This feature again gives a clue to the trouble man as to the location of the fault, which he knows to be a ground by his observations at the relay board. While the fault exists the operator continues all boxes in service by throwing switch M to the other position, which divides the system into two parts, each a complete circuit using the ground fault for a return, with all of the boxes in each part in series. For operation under these circuit conditions the switches L and R in local relay circuits must be thrown down. The operator will know as soon as the ground is repaired, for the relay levers will drop, and the register will run continuously until switches M, L and R are returned to their positions for normal operation.

In a similar manner it will be seen that the effect of a combination of faults, such as a ground and an open circuit, or several open-circuits, or several grounds, can be limited to render useless only the boxes between the faults, and this only as long as there is more than one fault. A consideration of these points will readily indicate the advantage of the new fire alarm system over the old one, which could have the
boxes in a large section of the plant rendered useless by a single open circuit, with no means of locating the fault except the one of testing out at each box along the line, which was a long process.

**ADDITION OF TELEPHONE AND SIGNAL CIRCUITS.**

The problem which confronted the engineers in adapting this system to the requirements of the plant in which it was installed was not one which concerned the fire alarm system circuit as much as the telephone and signal circuits. However, the principle of the fire alarm circuit given in the foregoing description had to be thoroughly understood, as the problem involved the use of this circuit for the telephone and signal system.

It was understood that the A. D. T. Co. used a telephone on its lines for communication between the line man and headquarters during tests on the lines. However, this was a one-sided method as it lacked one of the fundamental requirements of a system of communication, namely, the ability to call either station.

The first step in studying the problem was an investigation to determine what could be done in the way of installing the telephone and signalling system with the addition of only one wire to the circuit of the fire alarm and night watch service system. A circuit was connected up with several boxes and the necessary relays, and it was found that with a series buzzer circuit for calling the watchmen, operating
with a ground return, and a telephone circuit operating on the buzzer circuit and L2 of the fire alarm system, telephone communication could be established between any box and headquarters, even when talking with the reactance of twenty-five buzzers in circuit. While this seemingly solved the problem for normal operation, it was apparent that when switch M was thrown for grounded or open-circuit operation, the telephone and signal system would be interfered with to the extent of making it practically useless. In other words, when the fire alarm circuit had developed a fault, at which time the telephone and signalling system would be most urgently needed, this system would be useless and its presence would also interfere with the advantages of the fire alarm circuit as described previously.

When the results of this investigation had been reported and explained to the proper officials, the idea of attempting to economize by the use of a small number of line wires was given up, and it was realized that the slightly lower first cost of fewer wires would not compensate for the unreliable operating features involved. The problem then became that of adding a telephone and signal circuit which would be reliable and not interfere in any way with the fire alarm circuit.

The telephone system decided upon for this purpose was that manufactured by the Western Electric Company, known as the inter-phone system, and involved
the use of hand sets, which are carried by the watchmen in suitable cases, and when communication with the central office is desired, the plug on the cord of the hand set is inserted in the jack which is a part of the equipment at each box.

Requirements of the Telephone and Signal Circuit.

The requirements of the circuit are that the "plugging in" by the watchman would be signalled the central office operator, both visually and audibly, who could then with one operation, disconnect the signal and connect his telephone set with the line and talk with the watchman. Likewise the operator should be able to signal the watchman by some means which would attract his attention and persist until he answered by plugging in with his hand set.

Operation of Circuit.

The scheme for meeting these requirements is shown in Fig. 2. The battery current is supplied to the line through a retardation coil and when in operation the telephone instruments are each in parallel with the battery, as in the regular inter-phone system. The instrument at central is of the standard desk-set type, on a swinging bracket, with a receiver hook switch which is arranged to disconnect the instruments when not in use. As shown in Fig. 2 the connections are those existing for no conversation. When the watchman plugs in at one of the jacks, current from
the six-volt battery flows through his instrument and through the 34B signal, which is a sensitive relay, having a visual drop, causing the local circuit to close and operate the buzzer. Thus the operator's attention is attracted audibly by the buzzer, and visually by the signal, to the particular circuit on which the watchman is calling. He then operates key D, which when up disconnects the signal and connects his instrument to the line which is calling. The 34B signal has a gravity return on the drop, which causes the buzzer circuit to be opened as soon as the signal is disconnected. When the conversation is concluded, and the watchman has disconnected his hand set, the operator returns key D to the position shown.

In case the operator desires to call the watchman, he throws key D down, which closes the buzzer circuit and causes all the buzzers on the particular watchman's route, one at each box, to operate. Then the watchman, on reaching the next box on his route, hears the buzzer, and plugs in with his hand set. The same signal is then given the operator as when the watchman is calling, and when the key D is thrown up for talking, the buzzer circuit is disconnected and the telephones connected as before.

Special Features Added to Fire Alarm Circuit.

Before the fire alarm system could be installed it was found necessary to work out some special features in its use which were required to adapt it to certain
conditions at the plant which did not exist at the office of the A. D. T. system. These requirements were:

1. A fire call must operate two gongs and two registers in the fire house, and one register at the plant superintendents' office.

2. A watch call must be receivable without operating fire gongs or registers.

3. A fire call coming in when watchmen are being timed and fire gongs and registers are out of circuit, must be promptly switched to fire registers and gongs.

4. The circuit serving the lumber yard and dry kiln about one-half mile from the fire house, should be so arranged that fire calls from this circuit be also relayed to register and gong located there, but no watch calls should be thus relayed.

These conditions made a puzzling problem, which was solved by the introduction of two additional relays in the local register circuits of the fire alarm system, and several keys on the keyboard and desk of the operator, connected as shown in Fig. 3.

Operation of Complete System.

The scheme of wiring connections for the complete system is shown in Fig. 3, which shows two circuits, one of which is the circuit for the lumber yard and dry kiln.
The operation of the system as shown in Fig. 3 will be explained by tracing each of the calls from the boxes. At this point it should be stated that the box contact wheels are so connected to the operating mechanism that both the number wheels are on the same shaft, while the shunt contact wheel is on a separate shaft. When the box mechanism is operated by pulling the inside lever down, as for a fire call, the number wheels make seven complete revolutions, while the shunt contact wheel makes one complete revolution. When the box mechanism is operated by the watchman's key, the inside lever is pulled down one-seventh of the distance it moves during a fire call, and the number wheels make but one revolution, while the shunt contact wheel does not operate and the line is not shunted during watch call.

The number wheels have teeth which correspond to the box numbers and additional teeth to signal the letter F for fire call. In order that the letter F is not transmitted on watch call the contact springs are mounted on an arm which holds them from making contact with the wheels during the last part of the watch call while the F teeth are passing, but allows the number teeth to make contact during the first part of the revolution. Thus on a fire call the box number is signalled seven time while the letter F is signalled six times, the seventh revolution of the number wheels on fire call being the same as the one revolution of
the watch call, in which only the box number is transmitted.

In following the circuit diagram in Fig. 3 for a call, it will be seen that the connections between the boxes and relays are the same as in Fig. 1, except that the line rheostat and ammeter switch connections are shown. This rheostat is necessary to enable the currents for lines of different lengths to be adjusted to the same value, which can be read on the milli-ammeter by inserting the plug in the ammeter key switch for that circuit; as there is only one ammeter plug provided the liability of interference between circuits due to the use of the milli-ammeter leads in common is reduced to a minimum.

The local circuits of the relays are modified somewhat; the lamp relay circuit includes two lamps in parallel, one located on the relay board and the other on the telephone switchboard over the operators' desk (see Fig. 5); the register relay circuit has the additional keys A, B and C connected with the watch-register, which are necessary, with the relays shown, to fulfill the conditions enumerated on page 20.

Under normal operation, with the keys as shown, all calls come in on watch register as the fire alarm relays are shunted by the keys. Should a fire call come in while watchmen are being timed the operator will notice it because of the repetition of the box number and the additional signal F, which is dot-dash-
dot, and by throwing key A the remaining box number signals will operate the fire relay, and thus ring the fire gongs and record the box number on the fire registers. As the box wheels take fully two minutes to transmit the seven repetitions of the number for the fire call, it is very unlikely that the fire call will not be noticed before the seven registrations have been given; should this happen, however, the operator upon noticing the fire call on the tape can operate key C, which is of push-button type, and ring the fire gong to bring the fire departments attention and give them the number.

When watchmen are not being timed, and the operating desk has no one in attendance, the key B, which is of the lever-operated type, is left thrown up; (opposite to position shown in Fig. 3) and then all calls will operate the fire gongs and registers.

The fire gong and register will be operated at the dry kiln only for calls coming from that line, and then only when a fire call is sent in; this selective transmission is accomplished by means of the extra relay for this circuit and the extra contact points on keys A and B.

The resistance shown in series with each local register circuit was calculated as that necessary to be added to the resistance of the line and register to give a current of approximately one-third ampere.
The operation of the signals and keys for the telephone system has been previously explained in connection with Fig. 2, and the same circuit arrangement is shown in Fig. 3 except that the equipment for two lines is indicated.

INSTALLATION OF EQUIPMENT.

The installation of the equipment for the new fire alarm system was done by the plant wiring department. For the purpose of this description the installation may be divided into two parts, namely, that comprising the box stations and the wiring in the buildings, and between buildings and fire house, and that comprising the equipment in the fire house and its wiring.

In making the layouts for the wiring of the first-mentioned part the engineers were guided by layouts of the watchmen's routes prepared by the police department. These were block plans of the various sections of the plant drawn to a small scale, showing in colored crayon the routes traversed by the watchmen and the location of the box stations, which were twenty to twenty-five in number for each man. The wiring was so laid out that the boxes pulled by an individual watchman were on one circuit, thus keeping the register records separate for each.

After the wiring layouts showing the location of box stations and routing of circuits had been prepared, they were turned over to the wiring depart-
ment with a sketch of typical box connections as shown in Fig. 4, and the work on the plant wiring was begun.

Box Stations and Wiring.

In most cases the new fire alarm boxes replaced boxes of the old fire alarm system; wherever this was the case the old box was moved aside and temporarily connected as it was before. The mounting blocks for the new boxes were then put up and the conduit changes made. After the new wiring was installed for a circuit the old boxes were temporarily connected to the new wiring; in this way the old system was continued in operation with as little interruption as possible:

The wiring in the buildings was all installed in conduit, #16 rubber-covered wire being used and the five or seven wires of a circuit were all installed in one conduit, each wire being tagged at the boxes and junctions. In some cases where the routes of two watchmen were on different floors of the same building the main wires of two circuits in the building were run in the same conduit, in which event all the wires of one circuit were red in color and those of the other circuit were black. Wherever possible the conduit of the old system was used.

In the tunnels connecting the buildings with the fire house the circuits were paper-insulated lead-covered cables. At each end of the cable, where the
change to rubber insulated wiring in conduit was made, a standard cable junction box was used, containing a connection strip which could be used in making line tests.

Central Office Equipment.

The equipment in the fire house is that of the central office which forms the headquarters of the night watch system. This equipment consists of a relay panel, an operator's desk and telephone switchboard, and a battery panel, arranged as shown in Fig. 5. All of the equipment was especially designed for this purpose.

Relay Panel.

The function of the relay panel is to contain the central office circuit apparatus of the fire alarm and night watch service system, which consists of that indicated by the arrow in Fig. 3. This panel contains equipment for sixteen circuits, but ten of which were required for the installation at the time, six being allowed for future growth. The apparatus for two circuits is grouped in a vertical row, and eight of these rows extend across the panel. The equipment in each vertical row named in order from top to bottom of the panel is as follows: Two signal lamps, one for each circuit, two relays with switches R and L alongside each, and main switch M below, another group of two relays and switches, then two groups with one line
rheostat and ammeter key in each. In thus grouping the equipment for two circuits in pairs the relative location, upper and lower, is depended upon to distinguish the circuits, all of the upper circuit equipment being numbered odd, and the lower even. In the rear of the panel, near the top, an auxiliary panel is mounted, containing the fuses for each circuit, the resistances required in the register circuits and the connecting posts, each of which is lettered. The two fire relays in the local circuits of the registers are mounted in a dust-proof case on the wall in the rear of the relay panel.

Operator's Desk and Switchboard.

The function of the operator's desk and switchboard is to provide for the complete operation of the whole system under normal conditions by one man. On top of the desk the watch registers are placed, and the fire key A is located immediately in front of each, with enough space between it and the front of the desk for the tally sheets on which the watch reports are kept. Above the operator's desk and overhanging the registers is the telephone switchboard, which contains a small lamp, signal drop, and talking and signalling key, for each circuit, mounted in a vertical row, with equipment for sixteen circuits provided. At one end is the fire gong key C and at the other the master fire key B, while in the center on the under side is the call buzzer which is operated
by the signal drop. Between the telephone switchboard and the desk is a back-board on which are mounted jacks for the connection of the plugged cords from the registers. The use of these jacks enables the prompt removal of a defective register and its replacement by a spare one.

The watch registers are of the double-pen type that is, each register has two coils and two printing rolls which are independent of each other, but record on the same tape. The two records appear side by side and are not easily confused. The key A in front of each register is red-handled, and is so connected that pushing the lever handle to that side of the tape on which a fire signal is coming in will promptly put the signal on the fire registers. The fire keys B and C have red handles also, while all other equipment is finished in black, thus minimizing the liability of error in transmission of a fire alarm received during the hours when watchmen are being timed.

The tapes from the registers are passed through holes in the desk top and are allowed to accumulate in the interior of the desk until the watch is over, when they are rewound and filed for checking.

Battery Panel.

The battery panel contains the switches, instruments and protective apparatus used in charging the batteries and connecting them to the line. Two
sets of batteries for each purpose are provided: two of twelve cells each for the fire alarm system and two of three cells each for the telephone system.

The battery panel has the following equipment:

One Weston voltmeter, 0-50, model 24
One Weston ammeter, 0-10, model 24
One G. E. overload and reverse current circuit breaker, type C form G
Field rheostat with 4" diameter handle
Voltmeter switch, marked Gen., Ratt. #1, #2, #3, #4
Three-pole snap switch
Two four-pole double-throw special 25-ampere knife switches
Generator and battery fuses
One double-pole single-throw main generator switch
Two single-pole double-throw charging switches
Two single pole single-throw charging switches.

By means of the voltmeter switch the voltmeter can be connected to the generator or to any one of the four batteries. The ammeter is used only in conjunction with the generator, to determine the charging current. The circuit breaker is used to cut-off the charging current in case it exceeds a safe value, and also in case of failure of the supply current to disconnect the generator if the current should reverse and the battery should run the generator as a motor.

The motor-generator set was a 50-volt machine obtained by reconnecting the armature of a standard
110-volt motor, putting the field coils in parallel instead of series, and direct connecting this machine to a one horsepower 440-volt three-phase squirrel cage induction motor. The three-pole snap switch was used to control the motor, the fuses required in the motor circuit being placed in a suitable conduit on the rear of the battery panel.

The four-pole double-throw knife switches were used for charging and discharging the batteries, and were so connected that one battery in each set was discharging while the other battery was connected ready for charge. A throw of the switch interchanged the batteries, and the one which had been discharging was connected for charging, and vice versa. On account of the special design of the switch blades, which were extended below the hinge stud, it required a movement of only thirty degrees arc to pass from one position to the other; this meant that only by carefully trying to do so could the system be left without a battery through the main switch on the battery panel being left open.

Fuse protection was provided for all circuits on the battery panel except that of the battery discharging to the fire alarm system. On this circuit the fuses were provided on the rear of the relay panel, one for each circuit; this meant that the melting of a fuse would incapacitate only the circuit in which it was connected, and not the whole system.
The cabling switches were provided to enable the six-volt battery to be charged in series with the twenty-four volt battery, this arrangement making it unnecessary to obtain a low voltage on the generator.

The cells of the old fire alarm system battery were overhauled and used, and additional cells were provided to make up the number required for the new system. These cells are mounted on insulated sand trays in a ventilated enclosing cabinet of wood painted with acid-resisting paint and located in the basement of the fire house just below the operator's desk; the motor generator set was located alongside the battery cabinet.

CONCLUSION.

After the central office equipment had been installed and tested, and the plant wiring completed, the new system was put into service, one circuit at a time. This was done at the rate of two to three circuits a week, and took a month to complete. The old fire alarm boxes, which had been located in temporary positions alongside the new, were removed as soon as the new ones were connected up. The watchmen were instructed and changed over one at a time to the new routes.

During the change-over in connections there were certain fire alarm boxes temporarily out of service. Wherever this was the case, members of the fire department were detailed to the sections temporarily
without service, whose duty it was to send in an alarm at the next box in service, and direct the department in case a fire should break out in the section in which the boxes were disconnected.

A service test was devised by the engineers which had for its purpose the determination of the order of connection of the boxes in the circuit; this data was of use to the trouble man. In general the order of connection could be traced by following the conduit lines, but in the case of loops, it was possible that the order be interchanged by wrong connections at the junction boxes without affecting the normal operation of the system, as may be seen from a study of Fig. 4. The test consisted in operating two boxes at the same time, and noting which of the two recorded at the fire house; from Fig. 1 it is apparent that the box nearest the fire house in order of connection should shunt the one beyond it. The test was carried out with the aid of the telephones in receiving the report from the fire house, and in this way several misconnections were discovered on one of the circuits which contained a number of loops.

With the successful operation of this system the plant in which it was installed obtained the protective benefits of a service which exactly fulfilled all of the requirements realized as necessary through the years of experience with the old systems.
Diagram of F.A.& N.W. System Circuit

FIG. 1.
BUZZER AT FIRE BOX

WATCHMAN'S HAND SET

DIAGRAM OF TELEPHONE AND SIGNAL CIRCUITS

FIG. 2.
WIRING SCHEME OF COMPLETE F.A.& N.W. SYSTEM.

FIG. 3.

NOTE:
BATTERY PANEL WIRING
FUSE PROTECTION
NOT SHOWN.
NOTE:
IN CONNECTING TELEPHONE JACKS ALWAYS CONNECT LONG SPRING TO G WIRE.

CONNECTIONS FOR COMBINATION NIGHT WATCH AND FIRE ALARM BOXES.

FIG. 4.

G - GROUND WIRE.
T - TELEPHONE WIRE.
B - BUZZER WIRE.
L2 - FIRE ALARM WIRES.