AN INVESTIGATION OF FIRE ALARM SYSTEMS AND EQUIPMENT FOR RESIDENTIAL USE

THESIS FOR THE DEGREE OF M. S.

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1933

THESIS

Electrical engineering

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FOR

RESIDENTIAL USE

A

THESIS

Presented to

The Graduate School

of

Michigan State College

for the

M. S. Degree in Electrical Engineering

by

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East Lansing, Michigan

March 31, 1933

THESIS

PREFACE

An investigation of fire alarm systems and equipment, the complete results of which, together with descriptive matter and data concerning a relay and two thermostats, designed and built by us during our study, make up, in the following thesis, a fairly complete survey of fire alarm equipment adaptable to residential use.

The History of Fire Alarms, a part of this thesis, deals with equipment used in past times. Although in preparing it we have covered a large majority of the current sources of information concerning such history, it is by no means complete, as much material is not recorded in available papers.

In "The Fire Menace", a section of this thesis, we have tried to set forth data concerning the losses by fire in residences throughout the United States. This data convinces us that there exists a real need of adequate, economical fire protective equipment in the home.

With this need and certain practical considerations in mind, we have attempted to survey the fire alarm equipment available today on the market which might be readily adapted to this use. After making a rather complete survey, we believe there is little or no equipment on the market today which fully meets the requirements, as we see them, for use in the modern residence. Hence, we have endeavored to design and construct, as far as possible, during the time available to this work, equipment especially designed for residential use.

We regret that the time available did not permit a more complete survey of the problem. The construction of the relay required more time than was at first apparent. For this reason, we feel that, while substantial progress in the right direction has been made, there still exists certain facts concerning this subject which are worthy of further study. In the conclusions of this thesis we have set down facts pertinent to the subject which we did not investigate.

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ACKNOWLEDGEMENT

To Professor L. S. Foltz, Head of the Electrical Engineering Department of Michigan State College, we extend our sincerest thanks, for his most courteous supervision of this investigation and his many timely suggestions.

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THE FIRE MENACE

It is a well known fact that fire is not a new problem but is one that has been associated with every civilization. It is time that it be conquered, and the dangers from such be reduced to a minimum.

The purpose here is to bring out the grave danger of fire to dwelling houses, and the importance of providing suitable protection to reduce this to a minimum. A fire in the home is one of the most feared dangers. At the same time it is one for which there is a minimum of preparation. To the average citizen, a fire destroying his home means that he has to start over again. Possibly he has not only lost property but some of his family.

The fire menace is more appalling when it is considered from the standpoint of total losses in property and life. The President's suggestion of an international debt moratorium startled the world because of the fact that the United States would have to forego the receipt of a quarter of a billion dollars in principal and interest annually, yet our fire losses are almost twice this amount for the same period of time.

A point of much importance in consideration of property loss by fire is its prevalence. There has been a startling increase in the number of fires in residential property. Since 1924 dwelling losses have increased fifty percent. Poor construction, lack of fire stopping partitions and walls, substandard chimneys, combustible roofs and insufficient protective equipment are the leading and contributing causes of these fires. The dwelling losses in 1924 amounted to one hundred six million, four hundred eighty-two thousand, eight hundred ninety-seven dollars ($106,482,897) and in 1930 totaled one hundred fifty-nine million, eight hundred fifty-three thousand, twenty-four dollars ($159,853,024) or an increase of fifty percent. Dwelling losses in 1931 were thirty one percent of the total loss of the nation by fire.

Let us consider this loss to bring out some very important facts. Take as an example, the loss due to dwelling house fires for the year 1930. This means that each day there is an average loss of four hundred thirty-seven thousand, five hundred dollars ($437,500). Consider the cost of an average home as ten thousand dollars ($10,000); this means that nearly fifty homes are destroyed daily by fire; each day fifty families are turned out homeless and many with nothing left with which to rebuild. This is by no means an easy problem to solve and will, of course, take time but action in the near future is imperative. If conditions are left as they are, by 1936 our dwelling losses will amount to two hundred forty million dollars (240,000,000) or a quarter of a billion dollars.

As a final thought to fix in our minds the great property loss due to fire consider the following table furnished by the Lansing Division of the Boston Insurance Company. This gives the annual fire loss in the United States for the last fifty-seven years, that is, from 1875 to 1931 inclusive. It is well to keep in mind that in the last ten years, even though the total loss has remained the same, the loss due to industrial concerns has decreased and the loss due to residential or dwelling fires has increased, the impressive total being half a billion dollars annually. In order to reduce this waste of value, it is necessary to provide suitable protection in the way of residential fire alarm systems.

Annual Fire Loss in the United States for Fifty-seven

years. 1875-1931, inclusive

Year	Aggregate property loss
1875	$78,102,285
1876	64,630,600
1877	68,265,800
1878	64,315,900
1879	77,703,700
1880	74,643,400
1881	81,280,900
1882	84,505,024
1883	100,149,228
1884	110,008,611
1885	102,818,796
1886	104,924,750
1887	120,283,055
1888	110,885,665
1889	123,046,833
1890	108,993,792
1891	143,764,967
1892	151,516,098
1893	167,544,370
1894	140,006,484
1895	142,110,233
1896	118,737,420
1897	116,354,575
1898	130,593,905

Year	Aggregate property loss
1899	$153,597,830
1900	160,929,805
1901	165,817,810
1902	161,078,040
1903	145,302,155
1904	229,198,050
1905	165,221,650
1906	518,611,800
1907	215,084,709
1908	217,885,850
1909	188,705,150
1910	214,003,300
1911	217,004,575
1912	206,438,900
1913	203,763,550
1914	221,439,350
1915	172,033,200
1916	258,377,952
1917	289,535,050
1918	353,878,876
1919	320,540,399
1920	447,886,677
1921	495,406,012
1922	506,541,001
1923	535,372,782
1924	549,062,124

Year	Aggregate property loss
1925	$559,418,184
1926	561,980,751
1927	472,933,969
1928	464,607,102
1929	459,445,778
1930	501,980,624
1931	464,633,265

There is also a humanitarian viewpoint in consideration of the fire menace. The loss of property, however. appalling or enormous, cannot be compared with the needless loss of lives by fire. The annual toll of lives due to fire is fifteen thousand, which sounds even more astonishing when we find that this toll is larger than forty-one lives daily.

This loss in lives should be materially reduced by the application of every known means for preventing and extinguishing fires. In the extinguishment of fires time is of major importance. One minute may mean the loss of control of a fire. A reliable alarm reduces the factor of time to a minimum and gives firemen the maximum advantage, thereby reducing all losses.

If one gives thought to his home it is always his utmost desire that it be protected from all danger, especially that of fire. Protection from fire has always constituted a part of man's necessity. For example, consider the following precautions listed in an article on Fire Protection from the Annals of The American Academy of Political Science for September 1905.

"It is, therefore, seen that to use reasonable precaution against the conflagration hazard, we must:

1 - Curtail the size of risks so they cannot contain in any section an amount of combustible substance, which, if on fire at one time, is likely to place the district beyond control of existing facilities.

2 - Extend over most occupancies, the protection of a well designed signal system.

3 - Positively prevent communication from floor to floor of a building except through fire proof shafts.

4 - All exterior windows, including all windows on the street front,

except outside open areas, should be fitted with fire proof wire glass windows and, when exposures are severe, with approved shutters also.

5 - The public water and fire department facilities, in most instances, poorly prepared to meet severe conditions, should be radically increased. This may involve the introduction of a modern, adequate and direct fire pressure water supply."

Some such program might well be outlined for the protection of residences which would necessarily reduce the large annual loss due to fires.

In the present day, fire departments are equipped sufficiently well to quench fires if some suitable means of notification, dependable at all times, is installed in our homes to make the presence of fires known promptly. Thus there is necessity for residential fire alarms wholly applicable to all homes and financially available to the average working man.

Not only is it desirable to have fire alarms for the protection they offer but it is also important from the standpoint of insurance rates. These rates are based on fire danger. A definite value is placed on all fire protection measures, based on tests and trials by the underwriters with a close study of records and observation of actual operation. Insurance companies reduce their rates where suitable fire alarm signal systems are installed.

In conclusion it can be said that there is a necessity for a residential fire alarm system to reduce the annual one hundred fifty million dollars ($150,000,000) property loss, to prevent the needless loss of lives in dwelling house fires, to provide absolute protection from fire and to ultimately lower the insurance rates of home policy holders.

THE HISTORY OF FIRE ALARMS.

The purpose of the following pages is to give a brief review of commercial fire alarms that have been developed in the past. This will include not only devices that might be suitable for residential use, but also all phases of fire alarm development.

In a history of fire alarms it is rather difficult to pick any particular time from which to start. The earliest means of fire fighting was, of course, by means of the ladder and bucket brigade. As time progressed the necessity for a more dependable method of fire fighting was necessary. Probably the next step in the development was that of a gong arrangement and the well known fire wagons drawn by horses. The horse drawn fire wagon was durable and fairly efficient and served a long time. During its stay several methods were devised for notifying the fire department of a fire. During the last decade the horse drawn fire wagon has been entirely replaced by powerful and fast automotive fire wagons. Several fire alarm devices were developed and put into use, and we wish to give a review of the developments of this time. We will first consider some alarm devices that later formed an integral part of a general alarm system. Secondly, we will consider the development of the alarm system used in some larger cities of the United States and a review of their present status. Lastly, we will consider briefly some alarm systems used in foreign countries.

In 1905 two types of fire alarms were developed, one by a Scotch inventor and the other by a Dane. The former was of the automatic sprinkler type. This device rings an alarm, and starts an automatic sprinkler which acts as a first-aid appliance while waiting for the arrival of the fire department. In case of a sprinkler head becoming damaged, there is no danger of flooding the premises because in this system there is neither water or compressed air in the sprinkler pipes when they are not in use. In three tests on this sprinkler system, the results were very satisfactory and each time the fire was readily extinguished, in most cases before the fire brigade arrived from a distance of one and one quarter miles.

The Danish invention was of a different type and is confined to the ringing of the alarm bell. It is a very sensitive device and acts only on the application of a sudden wave of heat. The appliance consists of a U-shaped tube four inches in height filled with mercury. The upper parts contain sulphuric ether, and both ends are closed. One side of the tube is covered with non-conducting material. The device will not operate due to a gradual rise of temperature, whereas a direct wave of heat such as caused by a fire coming in contact with it causes the ether under the exposed glass to vaporize, forcing the mercury down which closes a circuit and rings an alarm. The chief objection to this device is the open circuit operation.

Around 1900, two American inventors, Siemens and Halske, invented a fire alarm device for notifying the engine house of the fire. It consisted of a clockwork system which was enclosed in an iron box to protect it against the elements and bad treatment. The person giving the alarm could start the clockwork by means of pulling a handle on the outside of the box. A message would thus be sent to the engine house. The telegraph apparatus placed in the engine house would write several times upon a tape the message or sign transmitted, while a bell would give the alarm to the firemen. The firemen had only to compare the sign described by the telegraph with those of a tablet placed above the apparatus in order to ascertain the source of the alarm. In order to permit this alarm being easily found at night a lamp provided with a red glass, to easily distinguish it from other lamps, is supported on the alarm box. A reflector illuminates the handle of the alarm and the directions for manipulating it, with a brilliancy equal to that of daylight.

Dissatisfied with the fact that this apparatus had one defect which, of course, was that of the intervention of man, these two American inventors, in 1903 invented a simple automatic alarm system. The most important part of this alarm was a thermometer tube, the bulb of which holds a spring switch out of contact. When the temperature rises, the bulb of the thermometer bursts, and the spring is released thus closing the circuit. The closing of the circuit gives an alarm in the engine house and if desired also a local alarm.

An automatic chemical fire extinguisher, very novel in design, was invented in 1902 by Mr. Louis Wirlum of Elsmere, Deleware. The device belongs particularly to that type in which a liquid is precipitated from one receptacle into another for the purpose of generating a gas fatal to combustion.

At Brussels, on the 26th of July 1902, Emile Guarini carried out some practical experiments with a fire alarm device invented by himself. This possessed the peculiar characteristics of notifying the engine houses automatically not only of the existence of a fire, but also of the name and the position of the building in danger of destruction. The mechanism of this device consists of a wireless transmitter and a wireless receiver. The transmitter is actuated by means of a mercury thermometer. The heat of a flame of fire causes the mercury to rise and make contact with a platinum wire inserted in the upper end of the tube of the thermometer, and thus closes an electric circuit which, by means of several mechanical devices, transmits the necessary message to the wireless receiver at the engine house.

Along this same line of wireless telegraphy for transmitting fire alarm signals comes the use of telephone lines for automatic fire alarm systems. This alarm uses telephone lines without interfering with the normal functioning of the phone system. It was designed for use in hotels, factories, mines, and public buildings, and for calling volunteer firemen in towns that have volunteer fire departments. Considered in its broadest aspect this alarm system consisted of a rotating switch, operated by a spring motor which automatically causes bells to ring in different circuits, a different number of times as a fire signal.

A little earlier than the previous alarms discussed is one put out by the Goldstien Fire-Alarm Telegraph System in 1895.

Essentially the system consisted of three parts, a thermostat which acts under the influence of heat, an annunciator, which receives the alarm from the thermostat, and indicates it by visual signal, and bell signal. The visual signal indicates the floor and room where the fire has been detected. The system also consists of a transmitter which transmits the alarm by wire to a certain fire station.

The thermostat consists of a hollow cylinder in which is located a washer of asbestos coated with paraffine. Beneath the washer lies a loose fitting piston which receives the pressure of a special steel spring. The spring is held under compression by a rod, the lower end of which is retained by two halves of a disk. These disks are held together by a solder which melts at a temperature of 150°.

The annunciator contains a clockwork, which automatically starts a bell ringing device both locally and in the fire station. The clockwork also operates shutters in such a manner to indicate the exact location of the fire.

The transmitter consists essentially of a magneto-electric machine, impelled by a weight which is released by an impulse of air from any thermostat in the building. The transmitter is also electrically connected with the central exchange of the local telephone company.

The thermoscope, a fire alarm device invented by Mr. Eugene Garretson in 1913, is an appliance in which the active element is a substance having a negative coefficient of electrical resistance. The thermoscope forms part of an electric circuit which also contains an alarm gong arrangement and an indicating device telling where the fire is located. At normal temperatures the resistance of the active element is high and the current passing through the circuit is not sufficient to work the alarm. When the temperature of the air surrounding the thermoscope rises to a certain degree, due to the heat from a fire, the resistance of the active material drops so as to permit the passage of sufficient current to give the alarm.

In most of the earlier automatic fire alarms, thermometers were arranged to close an electric circuit when a dangerously high temperature occurred. This type of alarm met with very little approval because it was likely to be operated when there was no fire, by means of an accumulation of heat in some badly ventilated spot. Also it quite often failed to operate when there was a fire until it was too late, merely because the temperature at the particular point where the automatic device was located did not happen to rise to the point for which the device was set. It was due to this that an American inventor, in 1910, designed a device which overcame these difficulties. This appliance operated to close an electric circuit where there is a sudden rise in temperature. It consisted of a metallic chamber which forms an air reservoir, and in case of a sudden rise of temperature the air is rapidly expanded and causes a contact terminal to rise and make contact with another. This closes an electric circuit to a bell or sprinkler or, in some cases, to both. The device will not operate due to a gradual rise in temperature, because the air expands very slowly and escapes through a small tube, thus preventing closing the contact terminals.

Another fire detector that is based upon the expansion of compressed air was invented by Charles H. Hayser of Newark, New Jersey in 1916. It was about the size of a shot gun cartridge, and the results of numerous tests conducted with it under service conditions disclosed the fact that it was a dependable means of detecting conflagrations. This detector is the electrical contact-making member of a fire alarm system. One circuit will take care of as many detectors as may be necessary to cover a given premises. This appliance depends for its operation upon expansion of a small quantity of imprisoned air. Like the above air reservoir type detector it is operated only by a sudden rise in temperature. It is also claimed that this device will work equally as well in ice houses, boiler rooms, or other places where abnormal temperatures are maintained for commercial use.

In 1920 William J. Luce, a fireman of New York City developed a fire alarm system which automatically telephoned its message to central, and thus to the fire house. Briefly the system consists of the use of thermostats located at intervals of twenty-five square feet or one for every room of the premises to be protected. These thermostats are placed in a circuit supplied with current by one or two dry cells. As soon as a fire breaks out in any part of the premises protected with these thermostats, the battery circuit is closed and, by means of electromagnets, the calling apparatus is set in motion. The release of a weight, by means of the energized electro-magnets, serves to lift the telephone hook, and start.

a phonograph. The record on the phonograph tells where the fire is, street, house, floor, and room if necessary, and repeats the message several times, assuring transmission of the message to the fire station.

The Gamewell Fire Alarm Telegraph Company of Newton Upper Falls, Massachusetts devised a compressed air fire alarm Siren. This Alarm Siren consists of a Diaphone, a compressed air reservoir for supplying the power to blow the Diaphone, a motor compressor to furnish this compressed air, and a special electrically operated valve which operates the Diaphone when a street box is operated.

There is very much in favor of this style air compressed system over the older systems.

First, it has greater volume of sound and greater carrying capacity.

Second, the space occupied is much less.

Third, one reservoir will do as efficient work as two or three reservoirs of the old style.

Fourth, it has a distinctive tone which cannot be confused with the tone of any whistle or other device.

It might be well to bring out here that this type of Siren is the most widely used to-day. At least fifty percent of the fire sirens used to-day are made by the Gamewell Fire Alarm Telegraph Company of Newton Upper Falls, Massachusetts.

An earlier type of fire alarm for the purpose of a general alarm for a small village was a gong arrangement. It indicated according to the number of strokes, where the fire was located. The bell was mechanically operated by a special lever arrangement.

The next few pages of discussion will be devoted to the development of the fire alarm system in New York City. Briefly, the main advances and reasons for the advances will be pointed out, along with a discussion of each.

In 1865 the fire alarm plant consisted of twelve bell towers or look-out stations located at points of advantage. The mode of operation was to watch for smoke or other indications of fire with a telescope and to signal by means of the Morse telegraph directly to the central office.

The primitive system was soon found inadequate and in 1870 a complete new installation was made at a cost of $150,000 including about 578 street alarm stations. The records of the department show that few difficulties were experienced for a period of ten years, and in fact many decided improvements in its working were effected. This system of installation is the basis of the present day telegraph plant in the Borough of Manhatten.

This system lasted with very few changes until about the year 1900. It then became apparent that it was necessary to make some very decided improvements, principally because New York was growing very rapidly and the equipment on hand was not of sufficient capacity, besides being rather make-shift and obsolete. The dangers from fire and the losses due to fires were rapidly increasing, and it was thus necessary to begin action for an improvement of the alarm system. in use. A movement for an improved system started in December 1904. In 1905 the Merchant's Association, the larger business interests, and several other organizations convinced the people that there was great need for improvement in the fire department. To finally convince the people of this fact, the New York Board of Fire Insurance Underwriters condemned the existing system. In March 1907 preliminary plans were formulated for a new fire alarm system but no immediate work of reconstruction took place until 1911.

The new system called for a central fire-alarm telegraph station in a building absolutely fireproof and devoted to no other purpose; a building which neither fire nor flood could damage. It was erected in Central Park in a place very much isolated. The telegraph and the telephone wires of the system were laid in underground ducts or subways, carefully protected throughout their courses from high tension or from possible contact with power circuits. The distribution of circuits was planned systematically as regards the territory served. The boxes were of the non-interfering type so that every signal would be recorded clearly whether sent in alone or simultaneously with other alarms.

It would be well to take time here to explain the old type street alarm boxes and the improvements brought about in developing the non-interfering type used to-day.

The making and breaking of a circuit for sending an alarm signal from a box, in a fire alarm telegraph system, is produced by the revolution of a disk notched in its circumference, so as to provide teeth which engage a follower, operating the circuit-breaking mechanism proper. The number and spacing of the teeth on the circumference of this disk give the signal for the individual alarm box, and thus indicate from whence the alarm comes. For example, consider the signal "123" being sent into the central fire station. In this case there is one tooth, followed after an interval by two, and after a second interval by three. This wheel or disk is caused to operate or revolve by clockwork when the handle on the street box is pulled by the person sending in the alarm. It makes a certain number of revolutions thus assuring that the message will reach the central station fire department headquarters. The circuit thus broken and made by the revolving disk affects a sensitive relay at headquarters, and this actuates a second circuit. The recording and indicating mechanism are connected in this second circuit in such a way that certain gongs or sirens can be operated and certain fire houses notified.

With several boxes on the same circuit it is quite conceivable that two or more boxes might be pulled at the same time, and the signal either be totally destroyed or come in badly jumbled. In case the circuit is broken no signal would be transmitted at all.

In the new New York box developed by Mr. Day and Mr. E. A. Faller, the first revolution of the wheel is a test to determine whether the circuit is so the message can be sent out. If it is perfect the ordinary transmission of the message takes place over the metallic circuit. If the circuit is faulty the line is automatically grounded on the side where the fault occurs and the signal is thus sent to headquarters through the ground and the one good metallic conductor. This is accomplished by having an armature released after a single revolution and then a snap switch connected to the circuit of the ground. In the meantime the operator at headquarters has received a danger signal telling him that a certain circuit is broken. He then closes a knife switch, putting on the particular box circuit indicated a powerful split battery sufficient to overcome any resistance so that the current interrupted at the box can be returned through the ground, and the signal received at headquarters in the usual way.

Another improvement of the new box is the fact that it is interchangeable, and it is remarkably simple in its construction.

New York is to-day well equipped with street boxes of this type and with an entirely modern central station. Also in the present system the one thing that was neglected in the earlier systems is the fact that there is chance for expansion and still maintain the old circuits in their present manner.

At about the same time the non-interfering street box alarm was developed in New York City, another big step was being taken in fire protective methods. This had to do with wireless telegraphy. Soon after the successful application of wireless telegraphy to moving trains for signalling, it was announced that it would be used in the fire alarm telegraph bureau for the City of New York with it's extensive water front and large shipping interests. Tests were made on an installation at Fire Headquarters, whereby an operator at the central station of the telegraph bureau was able to maintain communication with a fleet of fire boats as they proceeded about the waters of the harbor in answering an alarm or when they are in actual service, as for example, at a ship on fire at anchor. This equipment involves a simple installation of wireless apparatus at Fire Headquarters in East Sixty-seventh Street. There is similar equipment for the fireboat, which so long as it remains at its station is in touch with the telegraph bureau by fire alarm telegraph and telephone. The apparatus installed had at that time an effective working range of about twenty-five miles, and was capable of being tuned to any frequency. In the past few years this equipment has been largely replaced by radio which, of course, makes the plan even more effective. It is through such plans that the great water front interests are protected.

Thus we see that the fire alarm system of New York has been constantly changing to meet the required needs for more protection in general. Such has been the case in several other cities of the United States. Among them is Birmingham, Alabama, where in 1921 a complete modern fire alarm system was installed.

The system consists of two hundred fire alarm boxes on the street, twenty-five miles of underground cable, with a total length of 306 miles, 216 miles of overhead wire and a complete new central office which is fireproof in every respect.

The fire alarm boxes are so arranged that the chief or any of his assistants can go to the nearest box, plug in a special telephone set which is carried in the chief's car, and talk directly to the operator at fire headquarters. The alarm boxes are all on thirty circuits, the twenty engine houses are on ten circuits, and all the different circuits end at the central station.

The signals can be handled at headquarters in three different ways, automatic, semi-automatic, and manual. If the alarms come in only one at a time the automatic method is used, or if they come in a little oftener the semi-automatic method is used, and when they come in rapidly the manual operation is used.

There are three separate means provided for sending signals to the engine house. A register and sounder are mounted on the disk in the engine house, where a man is on duty and signals are received from the central office. A loud sounding gong is connected over a separate circuit to waken the firemen at night. If an alarm is received that does not call out that particular engine house the man on duty opens a switch which silences the gong and prevents awakening the firemen. In case of a small fire, telephone facilities are used to send out a particular company designated for such duty.

Accurate and automatic records of all alarms received and sent out are kept at headquarters. The box numbers are punched out on the register tape. This data along with time stamps, which record the day, hour and minute, furnish a permanent record for reference. The stamp registering device automatically takes care of the long months, short months, and leap year.

Back of the central office room, in which all the switchboard and control circuits are located, is a special room for storage cells which provide the current. There are 1800 of these cells to provide the energy to operate the system and furnish a reserve source in case of breakdown.

The fire alarm boxes on the street are of the Peerless, non-interfering type. Each circuit usually has ten or a dozen fire alarm boxes on the same circuit. Quite often two different boxes will be pulled at about the same time for the same or different fires. If these boxes interfered with each other neither message would be received with any accuracy. In case one box is operated while another box on the same circuit is sending in its signal, the second box will not interfere. At the end of each round the second box will test the line to determine if it is clear, and when it is cleared it will send its signal thus not interfering with the first signal.

Along this same line of fire alarm developments in different cities is that of the system in Nashville, Tennessee. This system is quite recent in design being entirely improved in 1931.

A new fire alarm building to house the fire alarm equipment is located away from power lines of the city in a district free from any interference. The equipment is Gamewell made, and manually operated. It consists of a thirty circuit control-board, and has some of the most improved modern equipment. One hundred additional new improved fire alarm boxes have been installed.

The fire department makes a quarterly inspection of all buildings and districts of prominence. This work is done by eighteen selected men from the fire department. The persistent inspection work and following up of all hazards it is believed has been directly responsible for a great portion of the reduction in fire losses that have been achieved. For the year 1930 the reduction in fire losses in the city of Nashville was between $400,000 and $450,000.

Another fire alarm control system that has received a great deal of attention in its development is that of Fort Worth, Texas which was completed in 1931.

The total value of this fire department including land, buildings, and equipment is $1,360,000. A total of two hundred seventy-one men and officers are employed, and twenty-four companies occupy twenty-one fire stations and man thirty-six pieces of motorized equipment.

In the fire department repair shop four mechanics are constantly employed repairing and rebuilding apparatus. A well organized drill school with first class tower equipment is maintained to assure the city of a well-trained fire department personnel.

The fire alarm apparatus was designed, built, and installed by the Gamewell Company, and is the latest type of fire alarm design. Leading into the central station office are twenty-three miles of underground cable, and seventy miles of overhead fire alarm wire, to which are connected four hundred eleven Gamewell street fire boxes.

We have thus far briefly covered some of the developments in the field of fire alarms, and also have showed how some of the fire departments in different cities have developed up to the present time. To show a comparison between fire alarm methods in the United States and some foreign country it will be well to discuss some developments in Germany along this line.

The German design of fire alarm system is somewhat similar to that of the designs in the United States excepting for minor details. The street alarm boxes are designed for open circuit operation, that is, when the circuit is broken the alarm is given. This is accomplished by a clockwork which is caused to be put in motion by means of pulling a lever or some such device. The signal is usually a certain number of gongs of the alarm bell made by a certain number of interruptions of the circuit. These interruptions are caused by the toothed edge of the disk in the rotating clockwork of the boxes. There are usually from ten to twenty boxes on a single series loop and thus the number of signals or circuit interruptions vary from one to twenty for the different boxes. When the message is received at headquarters (usually a central station where the fire department is located) it is only necessary to refer to the chart and compare the signal received with those recorded to determine from whence the alarm originated. This method is used in the smaller cities where a volunteer fire department is the sole support in case of a fire. Thus as soon as the alarm is received at fire department headquarters the man on duty immediately sounds a fire siren to arouse the general public. The siren is so designed that the location of the fire is designated by the number of signals from it.

Larger and more elaborate street alarm boxes are used for the larger cities. The box is very much like a clock case and is about two and one half feet long by one foot wide. It is provided with a large door and a small button with a glass pane, of about one sixty-fourth inch thickness, over the button. The purpose of this glass pane is to prevent false alarms being turned in, it being necessary to first break the glass, (the breaking of the glass being a damage to property except in case of fire) before pushing the button. Inside the box, in addition to clockwork, there is a lightning protector and contact key. The key is employed by the firemen for special purposes in calling the central station. There is also a loud ringing, mechanical, vibrating bell placed in these alarm boxes. This is released and allowed to ring for a certain length of time when an alarm is given. The purpose is to notify those passing by and the occupants of the burning structure that there is a fire.

As a receiving apparatus for this system, the direct indicating apparatus has proven itself very reliable. The indicating apparatus is mounted on the wall, or some such accessible place, in the central station and enclosed in a case with a glass front. In back of the locked glass door there is a signal annunciator disk and a line relay which transmits the incoming signals to the actual indicator or pointer system, the dial of which shows the various box numbers. There must be the same number of indicating devices as there are circuits in the system and the face of the dial in the indicating case is numbered with the number of street alarm boxes on that circuit. When an alarm is sent in by operating one of the street boxes the pointer on the dial starts moving around and stops at the number corresponding to the number of the box from whence the alarm was sent, thus locating the fire. When the indicating apparatus starts in motion, due to the incoming signal, an alarm is sounded to arouse the firemen or at least call their attention to the fact that there is a fire. This alarm is stopped only by opening the indicator case and returning the pointer to its original place. In case that all the firemen are not housed in the fire department headquarters a special alarm is sent directly to their home. No general public alarm is sounded because of the excitement it would cause in a large city.

In conclusion it can be said of the above German fire alarm system that it resembles very much the system used in the United States except for minor details. We have brought out the most important developments of this kind and have given each a brief discussion to show that in the past there has not been devised alarm equipment suitable for use in residences in the United States.

PRESENT TYPES OF COMMERCIAL ALARMS

Thus far we have shown the need of a residential fire alarm system to protect the homes of the United States, and given a brief discussion of the history of some of the fire alarm developments in the past. The purpose of following pages will be to bring out some of the present types of commercial alarms.

In a discussion of this kind it would be rather difficult to touch upon all the phases of existing systems. Thus in the material presented it will be our aim to present the developments of several of the more important present day devices used in signal systems.

Among the several companies providing signalling apparatus is the Howe Signal Company of Chicago, Illinois. The recorder is an automatic device for recording messages transmitted electrically from various locations to the central station. This recorder has the particularly important feature that the code signals are interpreted in clear type giving location, date and time. This prevents any mistakes being made in decoding the signals. The transmitter is a self contained unit used in conjunction with various types of actuating switches for all purposes of protective signalling. This transmitter and switching device can be used to transmit fire alarms or any other type of signal. The Howe Transmitter has three distinguishing and important features. They are non-interfering, which prevents any confusion of signals; they are successive when two or more are operated simultaneously; and they are repeating for special kinds of service, especially that of fire alarm.

The Howe Signal Company provides a special type of panel for control of all messages sent out by the transmitter. It is interposed between the transmitter and the recorder for circuit supervision and overload protection. The unit is entirely self-contained in a steel cabinet fitted for wall mounting. Careful design provides for full visibility of operating parts and easy access to the interior.

Among the manually controlled Howe Signalling devices is the Fire Alarm Box. It is of the break glass type and for operation all that is necessary is to break the glass. No further action is required and the code signal alarm selected for the particular box is transmitted to the fire department. The signal is repeated continuously until the glass is replaced or in some designs it is repeated only a certain, predetermined number of times.

In the supervision of automatic sprinkler systems the Howe Signal Company has devised some particularly important devices. The flow indicator is an alarm appliance for detecting the flow of water in the automatic sprinkler system. Howe Supervisory Switches are automatic devices used to detect the abnormal conditions of liquid levels, temperatures, pressures, control valves and electric circuits.

Howe Complete Systems consist of any of these various signalling devices, suitable control panels and alarm units incorporated into a complete alarm system.

The Gamewell Company of Newton, Massachusetts, is the manufacturer of several devices applicable to fire alarm systems.

The Gamewell Diaphone is a compressed air siren for the purpose of notification of a fire. It is particularly useful for a public alarm where volunteer fire departments exist. The Diaphone sounds a definite number of times which gives the location of the fire thus allowing volunteer firemen to go direct to the fire. The fact that it operates on compressed air makes it very applicable to any place since a compressed air unit for its operation can be easily installed.

The Dualarm is another Gamewell product. It is designed especially for public schools. This alarm device gets its name from the fact that it performs two functions simultaneously, that is, it empties the school of children by supplying sufficient alarms in all parts of the building, and it calls the municipal fire department at the same time without pulling a separate box. In other words the operation of one of the Remote Control Boxes, for use in case of fire, trips the Municipal Fire Alarm Box and at the same time trips the relay which operates the contactor and rings the local bells.

The Three-Fold Gamewell fire alarm box for industrial plants, railroad property, and so forth is another Gamewell product. This box has no particular features except the fact that it insures operation even if there is an open circuit in the line. In such a case a mechanism trips a switch and changes the open circuited part of the line to the ground thus affording a complete circuit and assurance of the signal being transmitted.

Another device that the Gamewell Company manufactures is a Rockwood Sprink-La-Stat. In a fire alarm detecting circuit there is placed a master model fire alarm box similar to the Dualarm discussed above. In the same circuit Rockwood Sprink-La-Stats are placed and in case of a fire the master box is automatically operated by a detecting device (thermostat). This performs two functions that of starting the sprinklers and notifying the municipal fire alarm central station thus calling out the fire department. This assures first aid in quenching the fire and has proven to be a very successful device for use in industrial concerns where the water from the sprinkler system can do very little damage.

The Holtzer-Cabot Electric Company of Boston, Massachusetts is a concern that develops alarm equipment for use in schools. Three principal systems are in use.

The first is for schools in cities or towns where a permanently manned fire department is maintained. This is a dual system by means of which fire alarm signals may be communicated simultaneously to the school and to the municipal fire departments. In this system fire drills may be sounded without any danger of calling out the fire department. The system consists of boxes for the purpose of sounding the alarm. These boxes have a glass panel in the door and in case of a fire the glass is broken and the inside lever pulled down as far as it will go. This process not only gives the alarm in the school building but gives a general alarm to the municipal fire department. In case it is desired to have a fire drill only the outside door is opened by means of a key and this disconnects the fire department. The operation of pulling the inside lever gives the alarm in the school building only.

In places where there is no permanently manned fire department, a second type of alarm is used. This system has all other advantages of the above mentioned system and the station boxes are operated in much the same way except that in case of a genuine fire the breaking of the glass causes the outside door to open and give access to the lever for operation. In case of a fire drill the box is opened by means of a key.

The third system is one designed for smaller schools and districts where the cost is a determining factor. This system has no connection with the city fire department. The system consists of small, break glass circuit boxes located at various places in the building, and a master box located in some convenient place. When a fire breaks out the alarm is given by breaking the glass in any one of the alarm boxes. A plunger is then released and closes the circuit connecting with the master box, thus releasing a pre-wound mechanism and causing the sounding of the bells in all parts of the building. In case of a fire drill a key is inserted in one of the alarm boxes which, of course, releases the plunger as above and causes the alarm to sound. In both cases, after the alarm is sounded, it is necessary to restore the master code box to its normal position by rewinding it.

The Holtzer-Cabot Electric Company also manufactures several other alarm devices. Among them are the following. The Non-interfering and the Plain Code fire Alarm Street Boxes. Fire Alarm Transmitters for both types of boxes. A silent test mechanism or attachment for fire alarm boxes to meet the requirements of several states, which specify the necessity of means for testing the box mechanism without sounding the gongs. Several signaling devices, which consist of different types of bells and sounding horns, are also a product of Holtzer-Cabot Electric Company.

A widely used fire alarm system of the present day is the Aero Automatic fire alarm. This is a product of the American District Telegraph Company of New York City, New York.

This system is a very sensitive system. The detecting element consists of a small copper tube less than one-twelfth of an inch in diameter. This tubing is placed around the ceilings or roofs of the premises to be protected. Air at ordinary atmospheric temperature is contained in the tube and in the case of fire the air becomes heated and expands. At each end of the tube there is a diaphragm or small metal box with real thin sides capable of being bulged outward due to air pressure. On each side of the diaphragm is an electrical contact and when the air in the copper tube is heated and caused to expand, the diaphragm becomes bulged and completes an electric circuit. Connected in this electric circuit is a transmitter which automatically sends the alarm to a central station and thus to the fire department. An annunciator placed on the outside of the protected premises indicates the position of the fire. A general alarm is sounded by bells throughout the premises.

There are several other American District Telegraph Company Products that are applicable to fire alarm control. Among them are the street alarm boxes, the break glass type of box used in public schools and such places, the automatic sprinkler system similar to all other automatic sprinkler systems, and several other alarm devices such as bells, sirens and gongs.

The Globe Automatic Sprinkler Company of Philadelphia, Pennsylvania is the producer of an automatic sprinkler system known as a Globe Saveall Automatic Sprinkler. The Saveall Sprinkler is the first approved sprinkler employing a solid chemical for its fusible element. This element has a definite fusing temperature, and as the surrounding atmosphere attains the temperature corresponding to the rating of the sprinkler, the chemical compound undergoes a physical transformation changing from a solid to a liquid and the sprinkler is in operation. This sprinkler is adaptable for all uses for it is manufactured in a wide range of temperature rating from 135^{o} to 340^{o}. Incorporated with this sprinkler system as with most others is the automatic sounding of an alarm with the start of the fire. The detector for closing the electric circuit of the alarm is the water in the sprinkler pipes. The water pressure acts upon a non-corrosive metal diaphragm. This operates a knife switch causing an electric contact and sounding an alarm.

The Globe Automatic Sprinkler Company also has on the market several fire extinguishers. The most important of these are the automatic type which are provided with a Saveall Detector unit similar to the one used in the Saveall Automatic Sprinkler system. This Saveall detector causes the extinguishers to be released. They are normally in an upright suspended position and when released they are in the operating position and automatically begin to apply the chemical extinguisher to the fire. Another type of automatic extinguisher is held in upright suspended position by means of a rope and fusible element. The heat of the fire releases the rope by causing the fusible element to liquify, thus releasing the extinguisher into operating position.

The Reichel System is an Automatic Fire Detection Service. It automatically detects a fire at its start and instantly transmits a signal to the Fire Department. This alarm system can be divided into the following parts: the detector, the fire detector circuit, the control unit, the master transmitter of street fire alarm box, the local manual auxiliary boxes, and the local alarm.

The Reichel detector is an electric thermopile. Each detector consists of seven couples in series, and each couple consists of one stud of bismuth and another stud composed of some other metal. One end of each stud is imbedded in a porcelain base so that heated air won't come in direct contact with it. The whole detector is mounted on the ceiling with exposed ends down. As long as there is a difference of temperature between the open end and the imbedded end, there will be a current flow. Since the open ends are extending downward from the ceiling in the case of a fire they will become much warmer than the imbedded ends and enough current will flow to operate the alarm. A gradual rise in temperature will not cause enough current to flow since the heat will be conducted away from the open ends fast enough to keep the difference of temperature down.

Each installation is divided into circuits. A circuit is composed of a single wire with the detectors connected in series. A contact relay is included in each circuit. The coil of the relay is so connected and adjusted in the circuit that the supervising or normal current will hold a pointer on the face of the relay in vertical position. In case there is a fault in the circuit there won't be any current flowing and this will be indicated by the relay needle moving to the extreme left. In case there is a fire the needle moves to the right and makes a contact which starts a fire alarm signal.

The contact relays mentioned above, are grouped in a hardwood cabinet, with glass door through which the dials can be seen. Under each relay is a printed designation of the area covered by the detectors on that particular circuit. This permits the cabinet to be used as an annunciator to tell from whence the alarm originated. Other relays and equipment essential to the system are assembled in this cabinet and the whole is known as the control unit.

The Master transmitter or street fire alarm box is located on the outside of the building on the street. It is the same type as any regular, city owned box. This is, of course, connected electrically to the city fire alarm wires so that operation of this box will transmit a telegraph coded number to the Fire department headquarters. The Master Street Box is automatically tripped from the control unit inside the premises. This is possible by means of an electrically connected special auxiliary attachment built in the Master Street Box. When operated automatically this attachment produces a mechanical motion equivalent to pulling the street box. This box can be used manually for any fire outside the premises the same as any ordinary street box.

The local manual auxiliary fire alarm boxes are located at the most advantageous points, such as a prominent exit, elevator landing or some such a place so that a local alarm can be easily given.

One standard type horn or gong, regardless of the number of circuits, is installed for a local alarm with each system. This alarm is located on the outside of the building near the control unit so as to serve to direct the firemen quickly to the control unit, and to act as a warning to the occupants of the building that a fire exists on the premises.

In conclusion, it should be understood that there are several other commercial alarm devices but that they all resemble, in a way, the appliances that have been discussed. The main thing to be brought out in this review of present types of commercial alarms is that there is not equipment readily adaptable to a residential fire alarm system.

FIRE ALARMS FOR RESIDENTIAL USE

In the selection of fire alarm equipment for residential use there are several factors which must be considered.

1. Reliability over a long period of time without servicing.
2. Simplicity.
3. Low First Cost.
4. Low Operating Cost.
5. Appearance.
6. Quietness of Operation.
7. Ease of Installation.

The reliability of the system is probably the most important feature of a system. It is needless to say that if a system is not reliable it fails to meet the need for which it is installed, namely, that of giving a fire signal when it is imperative that it should do so. In large buildings, factories, etc., many systems are in use which are regularly serviced by service men to maintain the reliability of the system, but could this servicing be made unnecessary by the use of a system which is reliable over a long period of time, much of the operating costs of a system could be eliminated. This has, as yet, not been satisfactorily accomplished, although much headway has been made in this direction during the past ten years. This is, perhaps, one of the prime reasons why fire alarm systems for residences has been, as yet, promoted unsuccessfully.

In a residence a different situation exists from that of a factory or large building. A system designed for use in a residence must be one which is reliable over a long period of time without servicing. The reason for this is obvious. Although a system might be installed which requires regular servicing, this regular servicing is almost impossible to maintain. Any meter reader will admit that getting access to residences is quite a problem. The lady of the house is quite frequently not at home during the day, and if she is, it is undesirable to her to have a service man taking the time necessary to service a set, especially if she happens to be entertaining. Needless to say, there would be times when the times between servicing of the system would be prolonged, and in such cases the reliability is, of course, seriously affected, hence the need of reliability over a long period of time.

The simplicity of the system is rather closely allied with that of first cost. It is also inherently a factor in the reliability of the system, since simplicity of mechanism makes for better reliability to a certain extent. If the simplicity of mechanism of operation can be brought into an actual reality, the cost of manufacturing the equipment can be greatly reduced, due not only to decreased amount of materials used, but also to decreased labor necessary.

Low initial cost is vital if the system is to be made available to the average man's residence. The prospective user of such equipment thinks more in terms of first cost rather than in saving over a period of time. Consequently, he is immediately prejudiced against such equipment to-day, for most reliable equipment on the market now is expensive.

The fourth factor to be considered in selecting a fire alarm system for residential use is that of operating costs. Although the average American man might readily see the advantages of such a system, it is doubtful whether he would use such a system if operating costs were excessive. In times of stress, when curtailing expenses might become imperative to him he is apt to class such a device as a luxury rather than the necessity which it is, and to discontinue its use. Especially is this true if the actual operating costs amount to an appreciable amount each month.

Little need be said concerning the appearance of the equipment. It must be neat, and the thermostats, especially, must be designed for inconspicuous ness and harmony with the color scheme of the room.

Quietness of operation, while essentially unnecessary, is rather easily achieved, and presents no very difficult problem.

Ease of installation is a vital factor. It is preferable, of course, to install such a system during the process of construction of the house, but obviously this does not fit the majority of the situations. The residential fire alarm system must be such that it can be neatly and easily installed in any modern residence at a low cost.

In looking over the field of available equipment we found no equipment which fully met all these requirements. Although each of the factors involved is more or less dependent on the others, and a compromise among the various factors is necessary, our investigation of commercial equipment available led to the following discoveries.

1. That most equipment on the market to-day is designed for use in large building, factories, etc.
2. That reliable equipment is expensive.
3. That reliable equipment is rather detailed equipment.
4. That most of the available equipment requires regular servicing.
5. That most systems have, in our opinion, excessive operating costs.
6. That most equipment on the market is neat in appearance.
7. That most equipment on the market possesses quietness of operation.

8. That most equipment on the market is fairly easy to install.

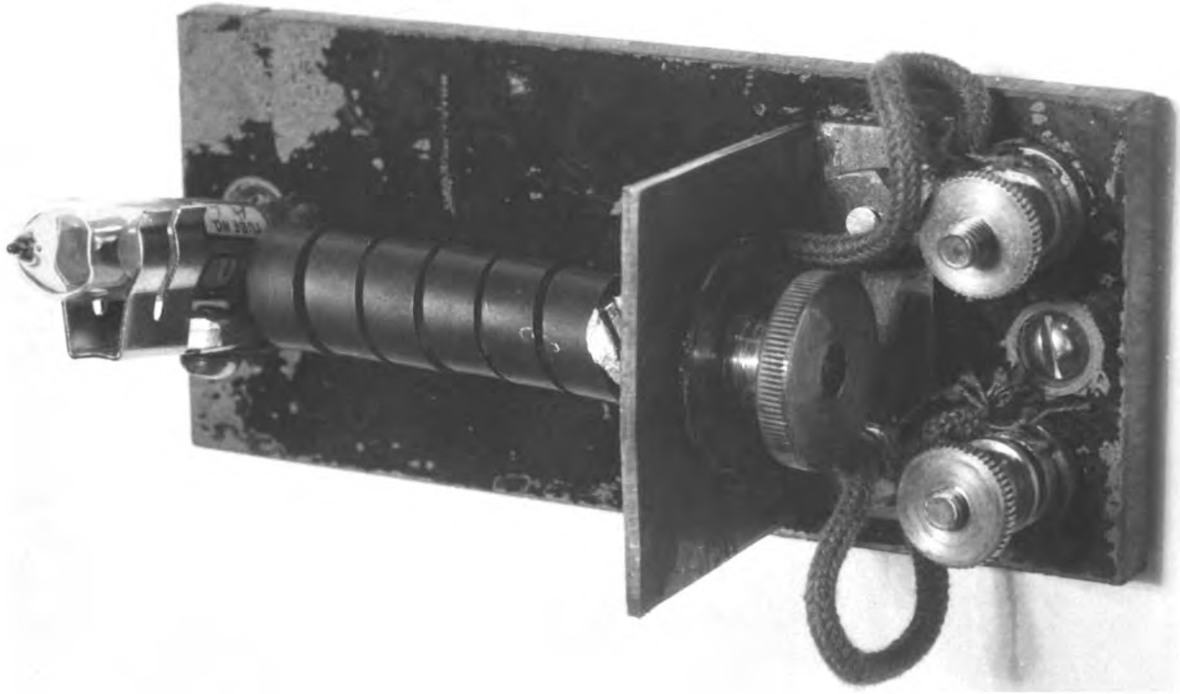
Or we might say, that such little equipment as exists which might be adaptable to residential use has the disadvantages of requiring regular servicing, high initial cost, and excessive operating costs.

It is probable that the foregoing statements are explanatory of the reason for lack of development in the use of residential fire alarm systems.

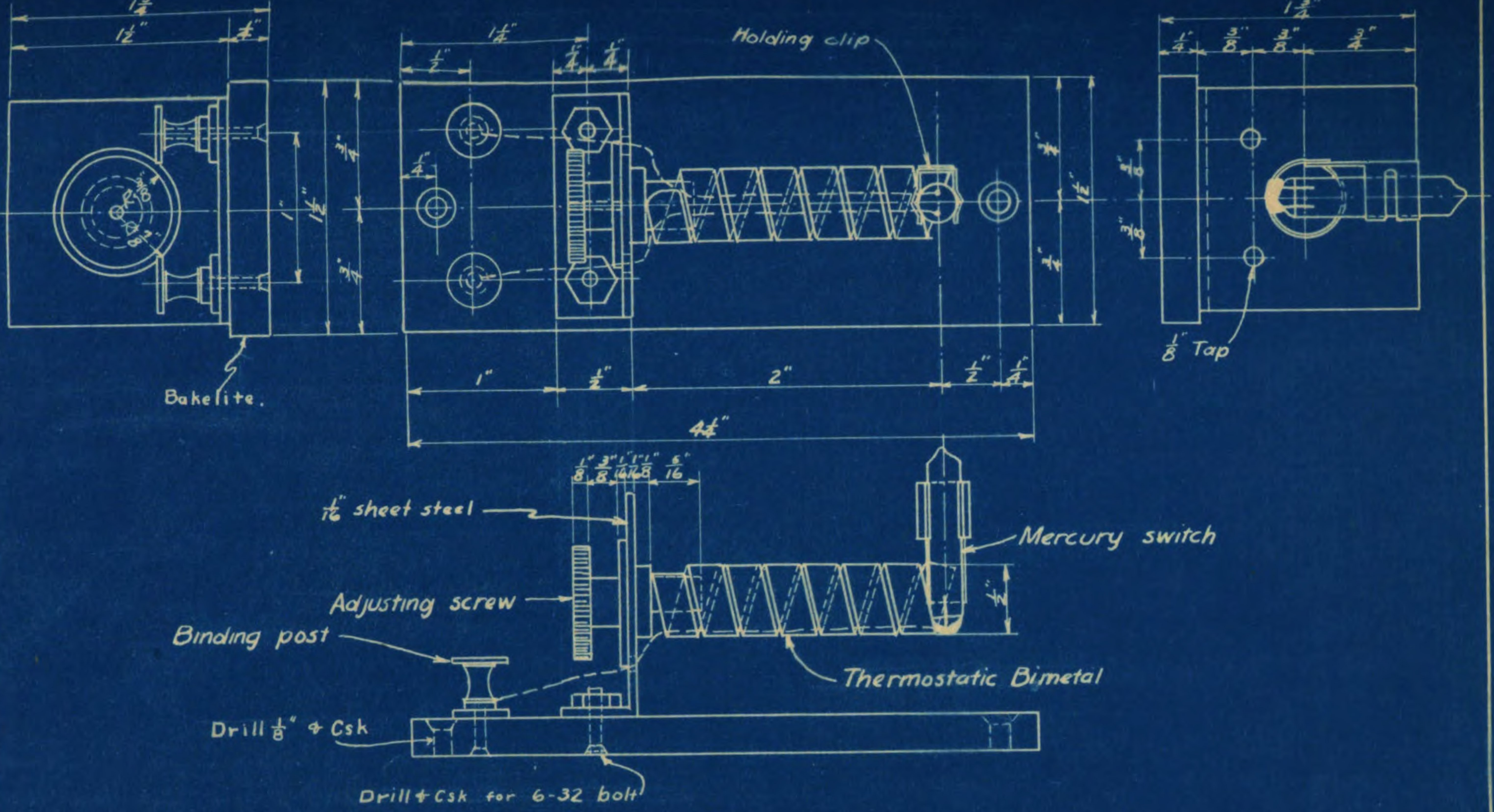
EXPERIMENTAL WORK

Keeping in mind the essential factors necessary for a desirable residential fire alarm system, we have endeavored to design equipment which will fully meet these needs. The first problem which we considered was that of suitable thermostats. Since the system must be reliable, and conforming with modern practice, have a pilot circuit which operates closed (opening in case of trouble or fire and giving the alarm) the thermostat must necessarily be one which opens the circuit when heated excessively. Although we found a number of modern thermostats on the market which meet requirements as to reliability, appearance, etc., all of them are rather expensive. With a view toward a more economical design of a reliable and neat appearing thermostat, we proceeded to design and construct two thermostats. The first of these is shown on the next two pages both by picture and mechanical drawing. The thermostatic element consists of bimetallic brass and steel, secured from the Wilson Company, Newark, New Jersey, and built into the form of a solenoid. As the element suffers a change in temperature the free end of the strip travels in approximately a circle, tipping the mercury switch which is firmly mounted to it at that end. This mercury switch (Con-Tac-Tor mercury Switch, Cat. No. C 1028, Time-O-Stat Controls Company) seems slightly larger than necessary, but has the most sensitive action of any we were able to secure.

This thermostat is rather sensitive to temperature changes, and can open or close on decrements of temperature change of less than one degree centigrade at higher temperatures.



THERMOSTAT



THERMOSTAT

Designed by: J.S. Scheurich
C.W. Woodard
M.S.C. 1933.

Below is listed the data taken on this thermostat at various operating settings. In taking this data a temperature controlled box was used to raise the temperature gradually to the tripping off point, and then gradually coiled till it again closed the circuit, both temperatures being recorded.

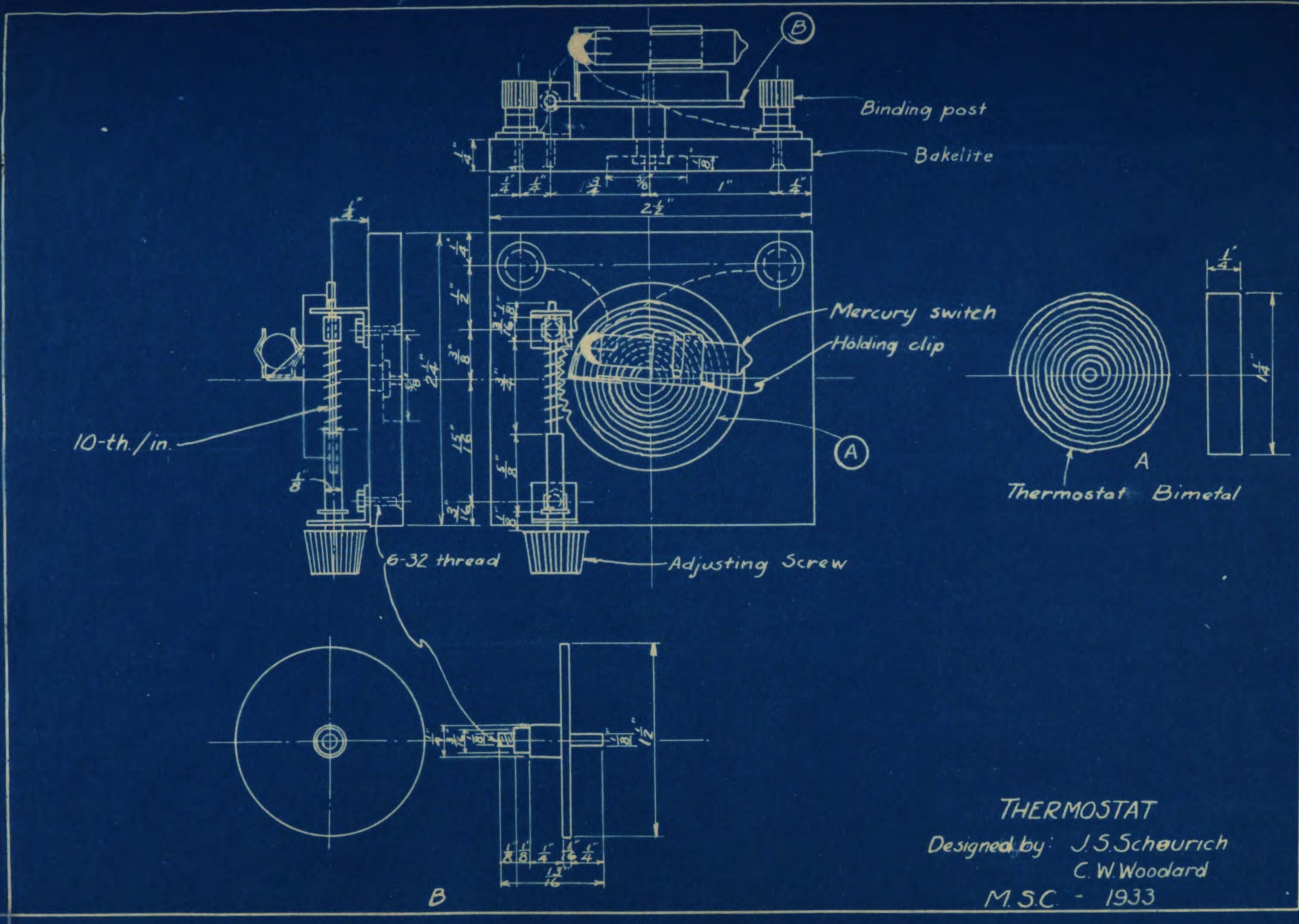
Opening Temperature Degrees Cent.	Closing Temperature Degrees Cent.
90	88+
90	89
89.7	89-
90	89+
90	88+
100	98+
99	97+
100-	98
100+	98.5
100	98
109.7	108+
110+	108+
110	108+
110	108-
111	109+
121-	120-
120	119
120	119
120	119
120+	119+
129	128+
129	128.5
129+	128-
129.5	128-
129+	128
139.7	139-
139.5	139
139+	139
139+	138.7
141	139+

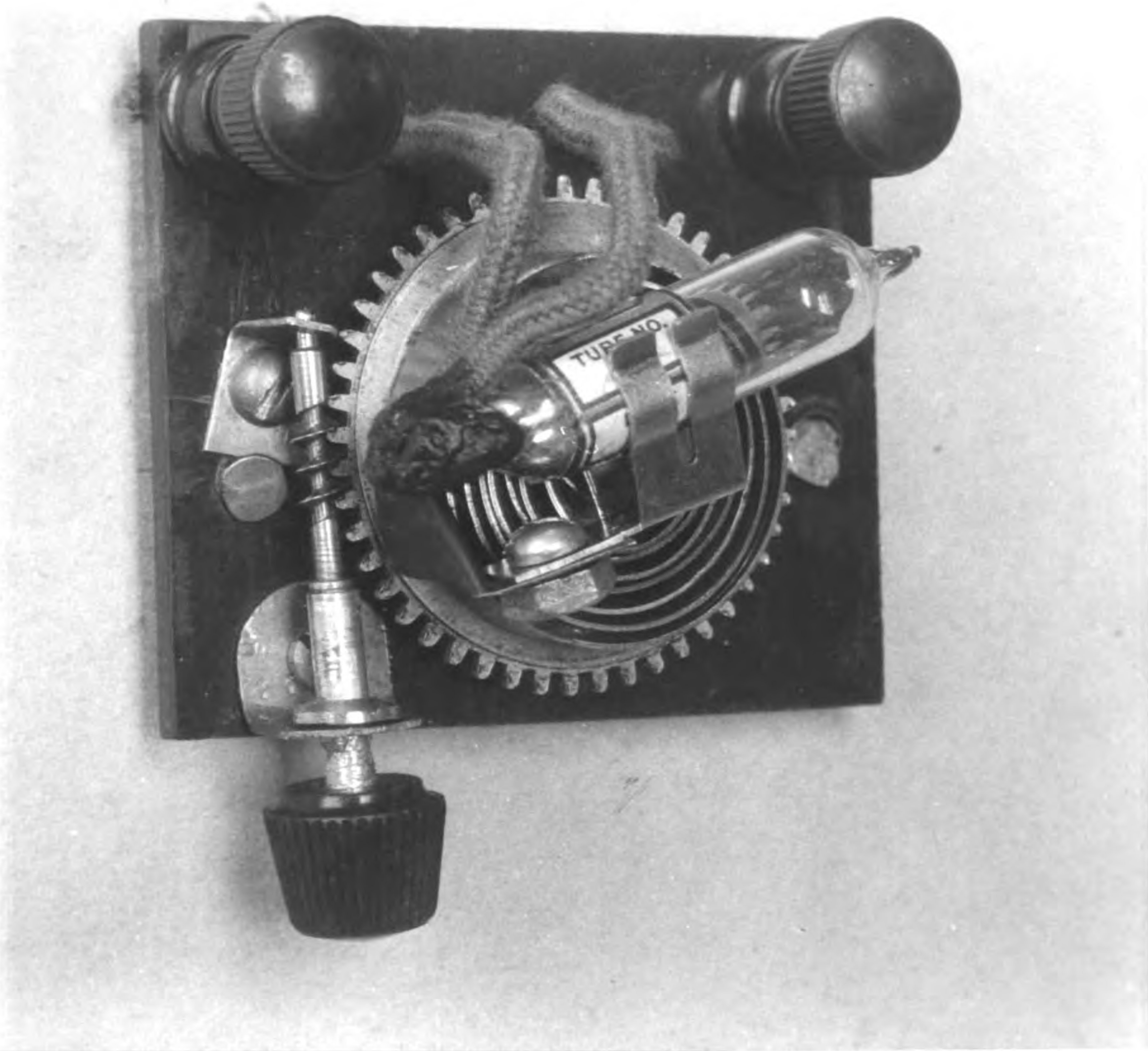
In endeavoring to decrease the size of the previously discussed thermostat, the following design was finally evolved. This thermostat, shown on the following two pages by picture and mechanical drawing, has a spiralled element. The same thermostatic bimetal is used in this thermostat as was used in the one previously discussed. The mercury switch is of the same type as that used in the case of the solenoid element thermostat.

The part marked (adjusting screw) in the drawing is an adjusting screw which determines the setting of the temperature at which the switch will open. Although a neater and more compact thermostat was secured in this later design, sensitivity was sacrificed as will be readily seen in the following data taken in the same manner as was the data on the first design.

The thermostat opens and closes the mercury switch on decrements of temperature change of approximately 5 degrees centigrade. For the purpose which this thermostat is to serve, however, this is of small consequence, since we are primarily interested in a thermostat which will reliably open the circuit at a fixed temperature and give the alarm. This the thermostat readily accomplishes. Further, we believe it can be favorably considered from a standpoint of low cost, which was our chief objection to available commercial thermostats.

The contacts of the thermostat are not liable to effects caused by the elements, since they are inclosed.


Binding post
Bakelite
Mercury switch
Holding clip
10-th./in.
6-32 thread
Adjusting Screw
Thermostat Bimetal
A
B
THERMOSTAT
Designed by: J.S.Schaurich
C.W.Woodard
M.S.C. - 1933



THERMOSTAT

Data on Spiralled Element Thermostat

Opening Temperature Degrees Cent.	Closing Temperature Degrees Cent.
90.5	82
90+	81
91.5	81.5
89.7	81
90+	81+
98	91+
98.7	92
100-	92+
99.1	91.5
100+	91.3
109.6	104
110.2	104+
109+	104.2
109+	103.9
110-	104.6
119-	115-
120.2	114.6
120.2	114+
121	115.2
120+	115.6
128	123.5
128.5	125
130.2	125+
129.6	124.5
129.6	125
141	134.7
141	135.6
140+	134+
141	135-
139	133+

With this final design we left the question of thermostats to turn our attention to the problem of a suitable relay. The problem which confronted us here was that of designing a relay which would conform to the following requirements.

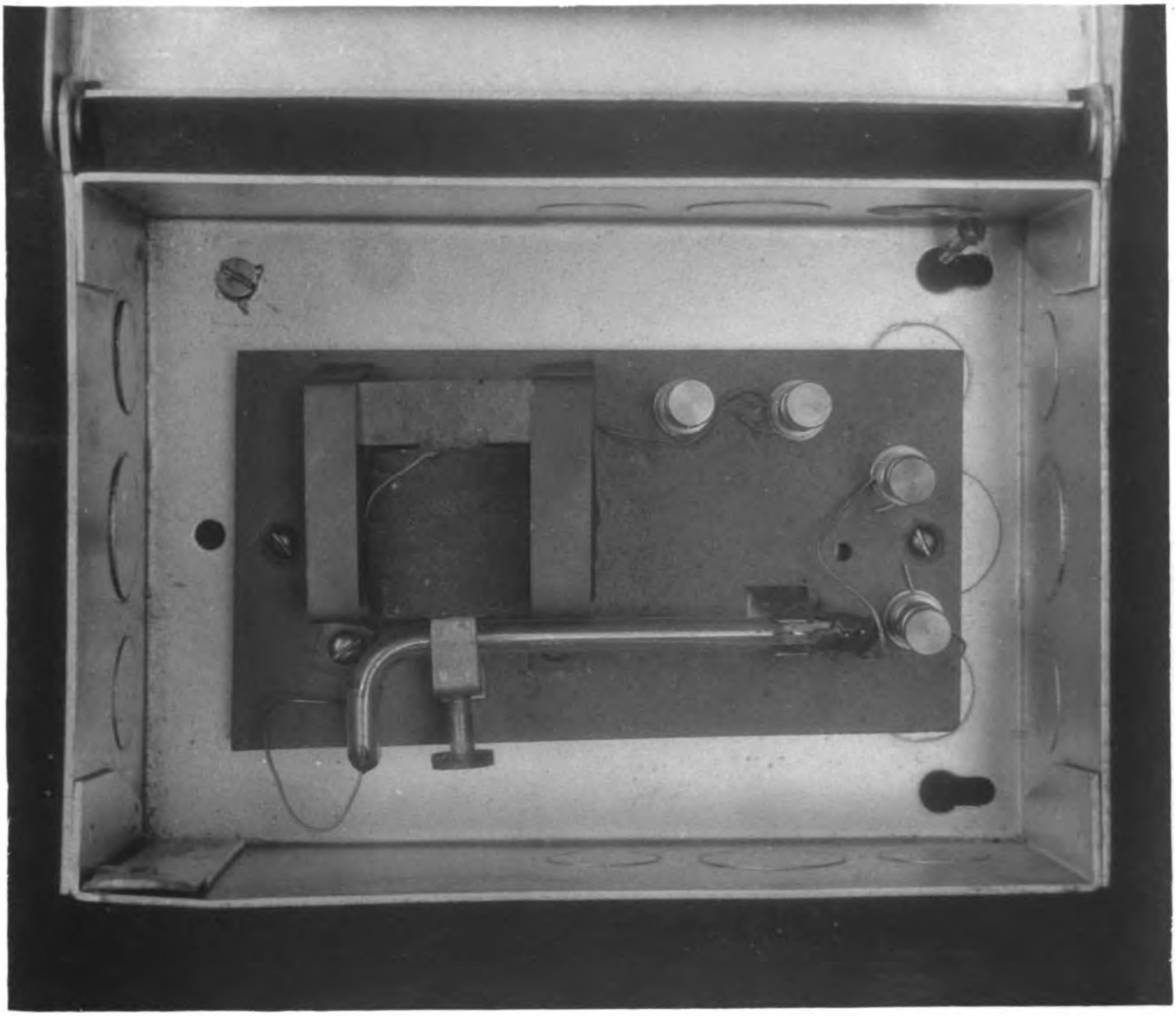
1. Close the secondary contacts upon failure of the exciting voltage.
2. Low initial cost.
3. Low operating cost.
4. Contacts which are not affected by the elements or ageing.
5. Reliability.

Most of the commercial relays investigated were found to be:

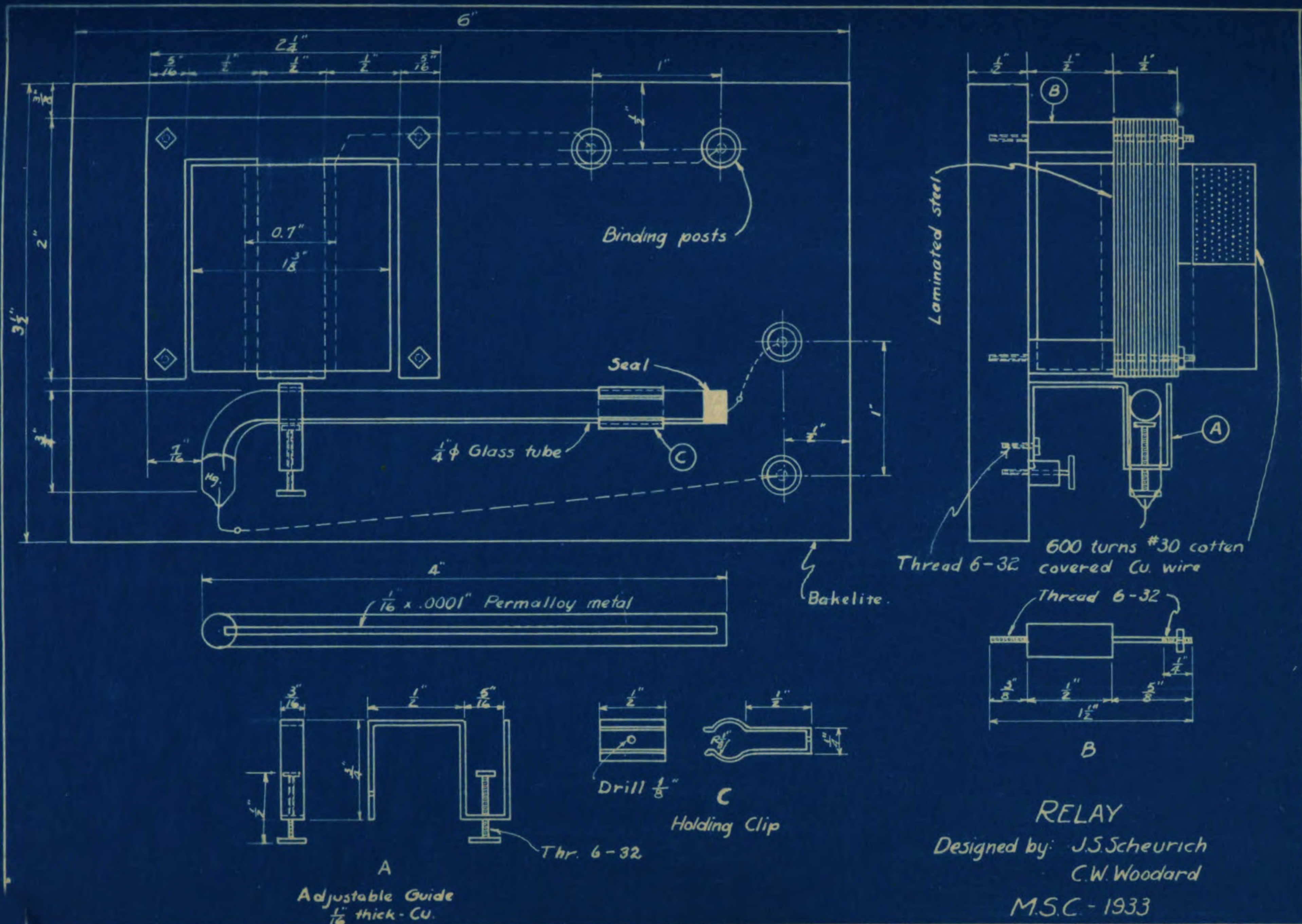
1. Rather expensive, if reliable.
2. Many were designed with secondary contacts exposed to air.
3. High initial cost of equipment giving reasonable operating costs.
4. High operating cost of equipment having a reasonable initial cost.

The problem was by no means a simple one. Three designs were worked out and the relays constructed. These failed utterly to meet our specifications. All of these designs were then altered with little success, and finally abandoned as useless for the purpose.

After considerable effort and profitable experience, a design meeting the requirements, as we see them, was finally evolved. It is shown on the two following pages by picture and mechanical drawing.



RELAY


Binding posts
Seal
1/4" ϕ Glass tube
Hg.
Bakelite.
1/16" x .0001" Permalloy metal
Laminated steel
Thread 6-32
600 turns #30 cotten covered Cu. wire
Thread 6-32
B
Drill 1/8"
C
Holding Clip
Thr. 6-32
A
Adjustable Guide
1/16" thick - Cu.
RELAY
Designed by: J.S. Scheurich
C.W. Woodard
M.S.C. - 1933

The exciting coil consists of 600 turns of number 30 cotton covered copper wire. The armature consists of a permalloy strip, possessing very high permeability, which was supplied to us by the Weston Electrical Instrument Company upon request. This strip, of dimensions .0001 x 1/16 x 4 inches, lies flat along the tube, the free end dipping into mercury and forming a closed circuit through the tube when the exciting coil is inactive. When the coil is excited the strip is attracted vertically upward, and floats with the tip free of the mercury. The length of stroke can be adjusted either by raising or lowering the tube with a given exciting current, or by varying the exciting current. The first method is, of course, the more proactical since a change of exciting voltage can not be readily had in most cases.

In running tests upon this relay (data listed on next page) we found that the relay would operate successfully on voltages from 2.8 to 7.1 volts. At 2.8 volts the stroke becomes a minimum and at lower voltages the strip fails to pick up. At 7.1 volts the stroke has its maximum value without making contact with the upper part of the glass tube. At higher voltages contact with the glass occurs, and the relay becomes slightly noisy.

We found the best operating voltage to be about 5 volts, the stroke adjusted at this voltage to approximately 1/16". At this voltage the coil takes a current of .15 amperes, and has a power consumption of .375 watts. Operating under these conditions the yearly operating cost would be (assuming 5 cents per K. W. Hr.) 16+ cents.

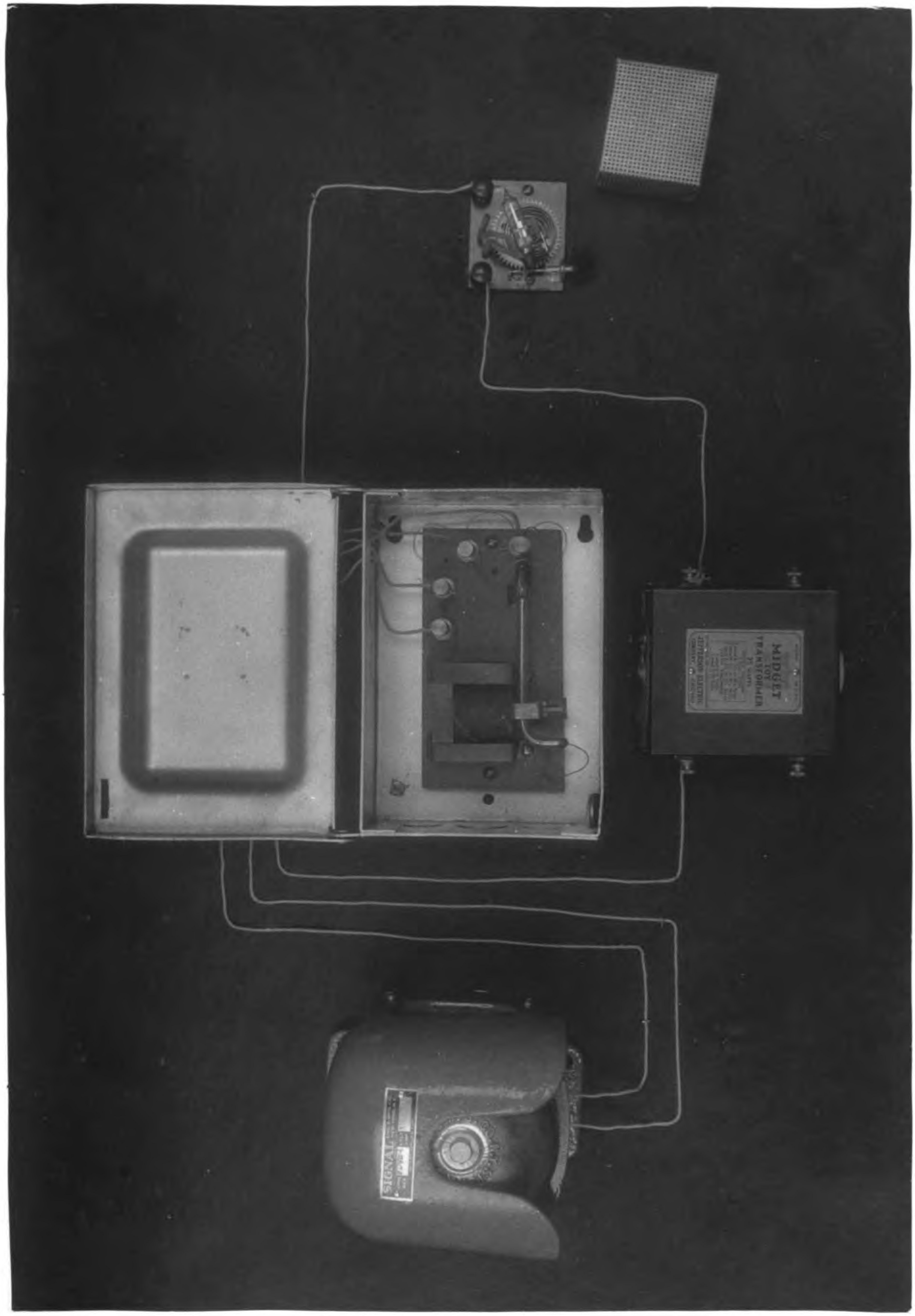
Another feature of this relay is its quick action. Of all of the commercial relays tested we found none which had quick enough action to open the secondary contacts before ringing of the bell took place, as in cases of resumption of power source after failure. This relay operates quickly enough to open the bell circuit before ringing of the bell can take place in such instances.

Exciting Current (Amps)	Term. Volts	Power Consumption (Watts)	Calc. P.F. (%)	
.08	2.8	.125	57.9	- pickup voltage.
.120	4.1	.250	50.9	
.150	5.1	.375	49.02	- Best Operating Conditions
.180	6.0	.566	52.4	
.210	7.1	.750	50.3	

Current Capacity of Primary: Does not show excessive heating at 1.5 amps.

Current Capacity of Secondary: Five Amperes - Ample capacity for any residential bell.

We believe that this design fully meets the requirements for residential fire alarm use, although further work toward a more compact design of this same type relay is desirable.


MIDGET
TOY
TRANSFORMER
SIGNAL

Conclusions

In making this investigation of residential fire protective equipment, as portrayed in the foregoing pages, we have arrived at several very definite conclusions. The problem which presented itself is by no means a simple one, and while we feel that we have made a very substantial progress in the right direction, during the time allotted to this work, we are convinced that a worthy field for study still exists in this subject, for we have by no means arrived at the final solution of the problem. For this reason we shall endeavor to set forth here the work which we believe necessary to bring this problem to its final solution.

There are three factors, aforementioned, which must be kept firmly in mind. First, reliability or certainty of operation over long periods of time without servicing. Second, simplicity or low initial cost. Third, low operating costs.

We believe that the relay designed and constructed by us embodies the first and third requirements in full, and believe that it can be modified to meet the second requirement in full. It should be possible to construct the magnetic arrangement using a single or double pole core, and to shorten the length of the tube without seriously affecting either the reliability or the operating costs. If this can be done, the design can be made much more compact, and will contain less actual material, with a consequent lowering of first cost. It might also be feasible to construct a relay along these lines which will operate directly from 110 volts, 60 cycles, thereby eliminating the use of a transformer. The cost of a suitable transformer might well offset the added cost of such a relay, however.

Another phase of the subject which time did not permit us to study was that of suitable bells for such a system, and in furthering this investigation we would recommend that this be studied.

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