SECTION 13B

AUTOMATIC BURNER IGNITION AND SAFETY SHUTOFF DEVICES

AUTOMATIC ELECTRIC SPARK IGNITION — FLAME SENSING SYSTEMS

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OUR MATCHLESS FUTURE

Pilotless ignition has long been a goal. It is the purpose of this paper to explore spark type ignition systems as not only a pilotless means to achieve ignition but a means to also monitor the flame.

Webster's definition of a spark includes "a small particle of fire or ignited substance emitted by a body, especially one in combustion." Sparks capable of ignition of hydrocarbons are produced in many ways. A simple way is to charge a capacitor to a given voltage and then discharge it. Another way is to provide a gap in the secondary of a transformer and through a triggering means supply an oscillating type discharge from the transformer. Other ways to produce spark include establishing a potential between a set of contacts and physically disturbing them so as to draw an arc between them. Of course, one can always use a flint and an abrasive wheel. All of these sparks are intended to provide ignition for various types of fuel and equipment.

Some fuels are more difficult to ignite than others. Energy levels required for ignition of hydrocarbon type gases have been studied by various scientific institutions in both the gas and oil industries. Energy levels required to ignite Number 2 fuel oil, for example, are approximately 10 millijoules. On the other hand, normal mixtures of methane and air can be ignited with as little as 0.4 millijoules. Sparks capable of ignition at low energy levels may even be non visible but yet capable of achieving ignition. Sparks created by capacitor discharges can enjoy the ability to traverse a substantial air gap. The ability to jump the air gap is dependent upon the voltage stored in the capacitor. The energy is easily computed from the relation $W = \frac{1}{2} CE^2$. Where W is the energy expressed in joules, C, the Capacitance, in farads, and E, the voltage. One joule is the amount of energy required to transfer one coulomb between two points having a potential of one volt. These sparks are easily produced at energy levels considerably in excess of that which is required for ignition but are still non hazardous because the time required for the spark to jump the gap is very short. Sparks produced by discharging a capacitor can be produced to jump gaps of ¼" to ½" in less than one microsecond. Their ability to ignite is excellent. 20,000 or 40,000 volts of potential at the electrode can be touched with a hand without danger because of the extremely low average energy.

One of the advantages in creating a spark of this type is to provide quick and adequate ignition because of the substantial air gaps. The large gap gives the opportunity for a spark to ignite a wide range of air-gas ratios by intercepting a considerable spectrum of these combustible gases.

A spark gap provides not only the physical geometry to cause ignition of combustible mixtures which are introduced between the electrodes but also offers the opportunity to determine the presence or absence of flame. It is well known that the impedance of the path of a spark is considerably lower in the presence of flame than in its absence. Although the primary purpose of creating a spark is to achieve ignition, to monitor the resistance of the environment of the spark can provide a means of detection. A complete ignition and detection system can be realized by establishing sufficient voltage at the electrodes to create the arc to achieve ignition followed by a reduced voltage potential between the electrodes to supervise the flame. If flame is absent, the impedance path will be high and the spark will be unable to jump the gap and the valve will then close. Interlocking the spark with valve operation is essential to not only accomplish ignition but also to provide for the safe ignition of the fuel intended. The primary safety feature is achieved by providing a means to spark which is electrically interlocked with the valve so that the valve can open only as a result of a spark being produced.

We are all familiar with turndown tests on various types of gas burning equipment at the A.G.A. Laboratories. Basically, this test insures that a pilot which is sufficient to hold the safety valve open shall also be adequate to ignite the main burner. The same protection can be built into any ignition system when the pressure becomes inadequate for the gas to reach the igniter. In addition to this pressure turndown protection, it may also be desirable to protect against voltage turndown in a similar manner. Let us assume that the line voltage to any ignition system also provides energy to the gas valve. If the voltage were reduced to a point sufficient to hold the gas valve open and insufficient to create a spark which is capable of igniting the burner, we would witness a dangerous situation. To protect against this hazard, a voltage turndown test should be conducted to insure that the valve will close at a reduced voltage before the spark becomes inadequate for ignition. Voltage turndown precautions become intimately interlocked with safety. Every precaution must be taken to insure that the spark which is produced is always capable of igniting the gas which is being introduced to the appliance.

Most comprehensive ignition systems include the concept of flameout protection but there may be areas where the electrical equivalent of a pilot may be satisfactory. Let's consider a system which proves the existence of a spark before any valve can open and then continually maintains the spark through the heat cycle. Let us further assume that this spark has the ability to ignite under all conditions and that in the absence of this spark for any cause, the valve will automatically close. If the flame should temporarily go out for any reason, the spark would continue and stand by for re-ignition as required. This is the same concept which now prevails in pilot systems. A spark under these conditions would probably be equally acceptable from a safety standpoint and perhaps even somewhat more desirable from the standpoint of being able to re-ignite any burner which was temporarily extinguished. For, in all probability, that which extinguished the burner would also have extinguished the pilot.

CONSIDERATIONS FOR IGNITION SYSTEMS WHICH USE SPARKS AS A BASIC MEANS TO ACHIEVE IGNITION

Some safety considerations for ignition systems which use sparks as a basic means to achieve ignition include:

1. A system which insures that the spark which has been produced is capable of ignition.
2. A system which is capable of proving the presence of the means to ignite before the gas valve is allowed to open.
3. A system which protects against all possible hazards of escaping gas.
4. A system which prevents the gas valve from opening in such case as the electrodes are shorted together.
5. A system which prevents the gas valve from opening in such case as the electrode circuit is open.
6. A system which prevents the gas valve from opening in such case as either electrode is shorted to ground.
7. A system in which all possible component failure results in valve closure.
8. A system which results in immediate valve closure in the absence of spark.
9. A system which provides an adequate ignition period followed by constant monitoring of the flame.
10. A system which uses acceptable and positive principles of flame detection.

Some additional considerations for ignition systems which use sparks as a basic means to achieve ignition include:

1. A system which provides sparks at an energy level capable of achieving ignition over a wide range of air-gas ratios.
2. A system capable of immediate re-ignition in case of momentary flame failure.
3. A system in which all components used in the system operate at non critical levels.

To protect against all hazards of escaping gas is a virtual impossibility but to protect against those which are controllable by any electrically operated valve is, indeed, very possible. It is the control of the valve which is mandatory in protecting against the hazards of escaping gas. Any system which cannot prove that the means to ignite is present before permitting the gas valve to open is not only inadequate but hazardous. To insure that the spark is capable of ignition is as difficult to prove as sugar is to prove sweet without tasting. Reasonable assurance of ignition can be achieved by establishing acceptable energy levels of sparks known to be capable of ignition. The hazards of any ignition system include the accidental opening of the gas valve. This is most unlikely to happen in a mechanical manner but can happen if electrical continuity to the valve is established. It, therefore, becomes imperative that any accidental shorting of the electrode circuit prevent the gas valve from opening or closes it in such case as it is already open.

Any other accidental shorting of either electrode to ground, for example, must be protected in the same manner. If, on the other hand, an open electrode circuit results in the valve opening without adequate ignition or, in the absence of a means to ignite, we would also realize an unsafe situation. Therefore, open electrode circuits must also result in closing the valve or prevent its opening.

A fail safe component system is a long sought after achievement in many areas of control systems. Many elaborate systems provide constant monitoring or checking for continuity or the lack of it in the circuit. A fail safe system can be realized if provision is made to insure that the valve will close or be incapable of opening under any possible component failure, either open or short.

Figure 1 illustrates a conventional manifold system which incorporates an A valve, a pressure regulator, a safety shutoff valve and an operating valve. The safety valve is interlocked with the thermocouple and pilot light. Many times various functions are combined in one enclosure.

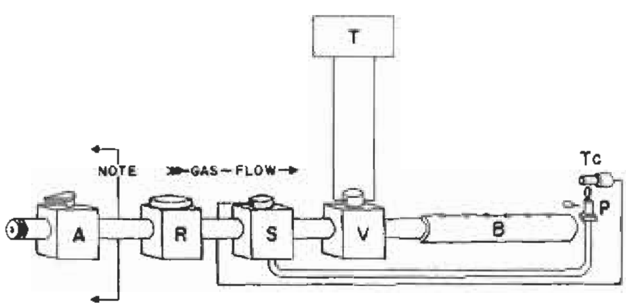

Figure 1 — Conventional Manifold System for Gas Fired Devices.

A = MANUAL SHUT-OFF VALVE
R = PRESSURE REGULATOR
S = SAFETY VALVE
V = MAIN VALVE
T = THERMOSTAT
Tc = THERMOCOUPLE
P = PILOT
B = BURNER

NOTE:
MANUAL SHUT OFF IS ALWAYS REQUIRED AND IS SOMETIMES PROVIDED BY MANUFACTURER OF EQUIPMENT.

An understanding of the conventional pilot operated system is helpful to establish an understanding of an automatic direct ignition system. The pilot shown in Figure 1 is a constant burning pilot. The thermocouple energizes a small DC coil which holds open the safety valve. This permits the thermostat to call for heat and energize the operating valve. When the thermostat is satisfied, the valve closes. The pilot continues to burn.

A direct ignition system illustrated in Figure 2 incorporates an A valve, pressure regulator and an operating valve which is interlocked with the automatic ignition system. This is called direct ignition.

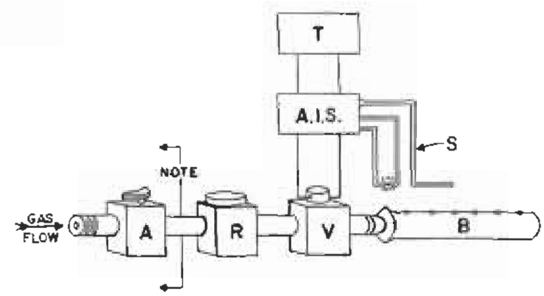

Figure 2 — Modified Manifold System (for Gas Fired Devices) with Spark Ignition — Flame Sensing Control System.

A = MANUAL SHUT-OFF VALVE
R = PRESSURE REGULATOR
S = FLAME SWITCH
V = MAIN VALVE
B = BURNER
T = THERMOSTAT
A.I.S. = AUTOMATIC ELECTRIC SPARK IGNITION — FLAME SENSING SYSTEM

NOTE:
MANUAL SHUT OFF IS ALWAYS REQUIRED AND IS SOMETIMES PROVIDED BY MANUFACTURER OF EQUIPMENT.

The operational sequence is as follows. When the thermostat calls for heat, a spark is produced and simultaneously the gas valve is opened. A timer is incorporated into the system which provides a trial-for-ignition period. If ignition is achieved, a heat sensing switch holds the gas valve open throughout the duration of the heat cycle. If ignition is not achieved, a timer opens the circuit to the valve. The trial-for-ignition period ends and the valve closes.

Figure 3 illustrates an automatic spark ignition system which incorporates its own detector. The detector in this case is the same set of electrodes which provide ignition. In this system, the trial-for-ignition period is followed by a reduced

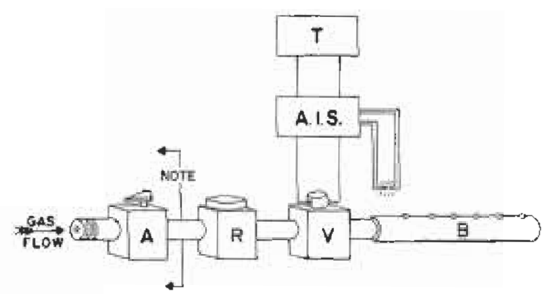

Figure 3 — Modified Manifold System (for Gas Fired Devices) with Spark Ignition — Flame sensing Control System.

A = MANUAL SHUT-OFF VALVE
R = PRESSURE REGULATOR
V = MAIN VALVE
B = BURNER
T = THERMOSTAT
A.I.S. = AUTOMATIC ELECTRIC SPARK IGNITION — FLAME SENSING SYSTEM

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voltage at the electrodes which provides for continuation of spark if flame is present. In the absence of flame, the spark is unable to jump the gap and the current dependent valve closes.

Figure 4 is a block diagram which further explains the sequence of operation in the system of Figure 3.

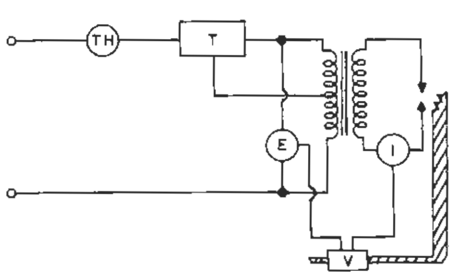

Figure 4 — Basic Functions of Ignition System.

TH = THERMOSTAT
T = TIMER
E = VOLTAGE SENSING RELAY
I = CURRENT SENSING RELAY
V = GAS VALVE

When the thermostat calls for heat, a high voltage spark is produced at the electrodes. A current sensing relay opens the gas valve as a result of current in the transformer secondary. After ignition has taken place, the timer shifts to the increased primary turns and lowers the voltage at the electrodes. In the presence of flame, the impedance path is lower which permits the sparks to continue to jump the gap. In the absence of flame, the impedance path is too high for the spark to jump the gap at the reduced electrode voltage. When the sparks stop, the valve closes. You will note that the valve operation is dependent upon current flowing in the secondary and the presence of voltage in the primary.

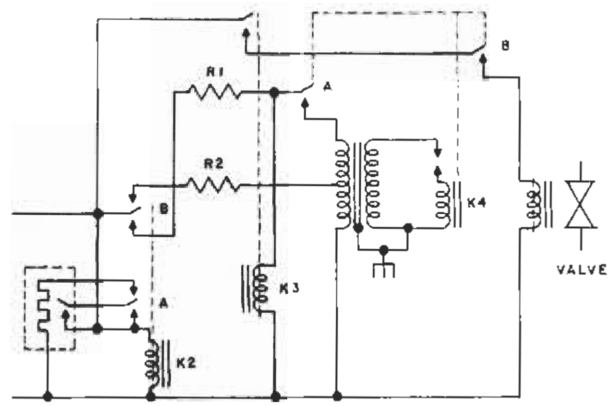

Figure 5 — Automatic Ignition and Detection System.

Figure 5 is a schematic diagram of an automatic direct spark ignition system. The basic components in the system are a timing means, a non energy limiting transformer, a current sensing relay, K4, in the secondary and a voltage sensing relay, K3, in the primary. The timing means is an electrothermal switch which provides for an ignition period and then switches the transformer to a constantly monitoring voltage. It operates through a relay so that it is only in the circuit during the ignition cycle. The current sensing relay can pull in only as a result of sufficient current in the secondary. When the current falls to a level which impairs the spark's ability to ignite, this relay drops out. Its primary function is to prove that there is current between the electrodes adequate to insure a spark which is capable of ignition and also to prove the existence of a spark. If the electrode circuit is open or shorted to ground, the current condition for opening the gas valve is not met.

The voltage sensing relay's primary function is to protect against a shorted electrode condition. If the electrodes are shorted together, an impedance change is reflected and witnessed across Resistor R1 which drops the voltage across the relay. The resulting voltage across relay K3 is reduced approximately 25 per cent which is inadequate for the relay to hold in and, consequently, drops out as a result of the shorted electrode condition. If the shorted condition is of brief duration, the removal of the short will result in recycling of the system. This is true only if the electrodes have been heated by the flame so that current continues to flow briefly with heated electrodes and no flame. If the short is of considerable duration, allowing the electrodes to cool, and then the short is removed, the voltage sensing relay temporarily pulls in but is unable to recycle the system because of the interrupted circuit from the second set of contacts in the current sensing relay, K4. This prevents the system from recycling and results in lockout. Breaking and remaking the line is required to recycle.

Any ignition system which is sensitive to erratic conditions of flame may cause nuisance dropouts of the burner. The sparks are purposely permitted to continue under temporary flameout conditions in order to protect against nuisance dropouts. Once the electrodes are heated, sparks continue due to the effect of ionized air and a reduced impedance path between the electrodes even in the absence of flame. Therefore, if the flame is temporarily removed or extinguished and subsequently the gas is re-introduced, it will immediately re-ignite as a result of the continuation of sparks. If the burner is extinguished for too long a period, the electrodes will cool substantially and the di-electric becomes high enough to cause the sparks to cease, resulting in immediate valve closure. In summary, and most importantly, there is no time when gas can be admitted to the burner when a means of ignition is not present. As soon as the means to ignite disappears, the valve always closes.