United States Patent [19]

Faulkner

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[45] **July 10, 1973**

[54] FUEL-LEAK DETECTOR AND SAFETY SYSTEM

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[21] Appl. No.: **147,421**

[52] **U.S. Cl.** **431/16,** 431/22, 431/31, 431/46, 431/51

[51] **Int. Cl.** **F23q 9/08**

[58] **Field of Search** 431/16, 22

[56] **References Cited**

UNITED STATES PATENTS

3,194,296	7/1965	Brown	431/16
3,223,138	12/1965	Brown	431/16
3,358,732	12/1967	Stuart	431/22
2,583,842	6/1971	Hancock et al.	431/16

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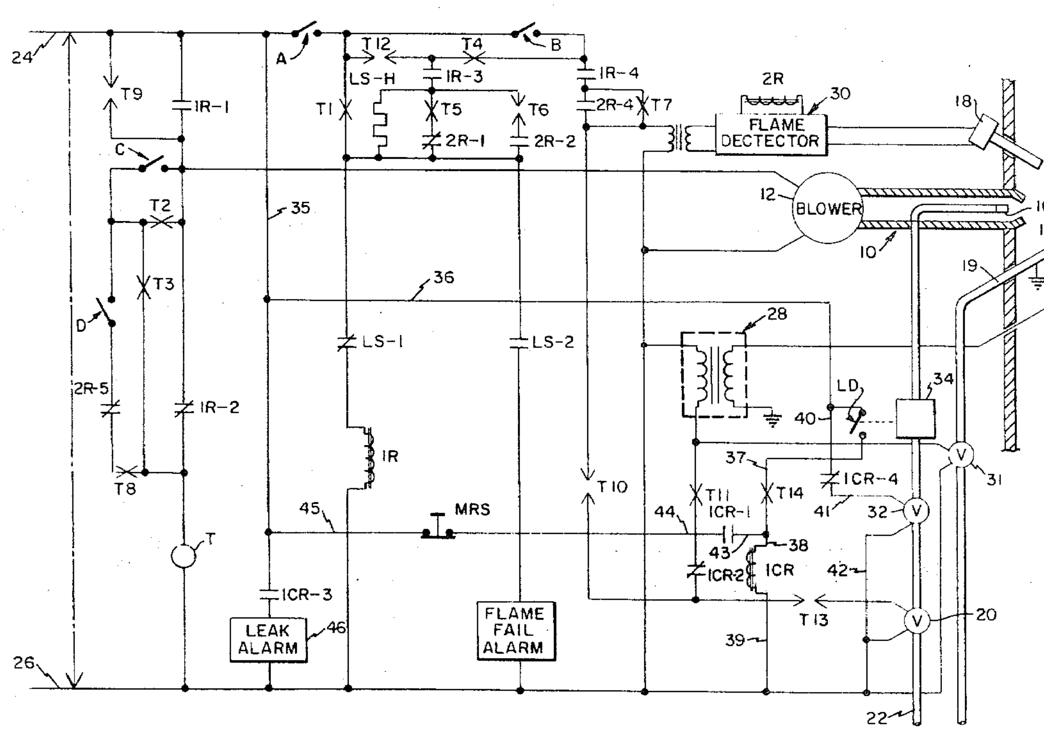
Attorney—Steward and Steward, Merrill F. Steward and Donald T. Steward

[57] **ABSTRACT**

A safety control system for detecting and stopping leakage of fuel through the fuel-valve in burner fully automatic installations subject to such leakage problems because of the presence of fuel under pressure at the fuel-valve for periods of time when the burner is not actually lighted. The system includes a lead-detector, such as a pressure switch, located downstream of the main fuel-valve for closing an auxiliary fuel-valve installed in tandem with the main valve, so that when leakage through the main valve occurs, the auxiliary valve closes and immediately stops the leak. It also trips a lockout circuit that prevents re-ignition of the burner. A discriminator device is employed for nullifying the action of the leak-detector on normal flow of fuel to the burner nozzle. While the leak safety of the present invention immediately stops the leak by closing the auxiliary fuel-valve, it permits the master burner control to progress through its normal cycle of operations during both its shut-down and start-up periods to the point just before ignition takes place, so that any fuel that may have leaked will be purged during the purge periods of the burner cycle, thereby providing a safeguard against ignition of the leaked fuel when the burner is restarted. A leak alarm is provided to signal when the leak-detector senses a fuel leak, and a separate manual reset device is provided so that the burner cannot be restarted accidentally following what might be erroneously thought to be a routine flame-out.

15 Claims, 4 Drawing Figures



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3 Sheets-Sheet 1

FIG. 1 (PRIOR ART)

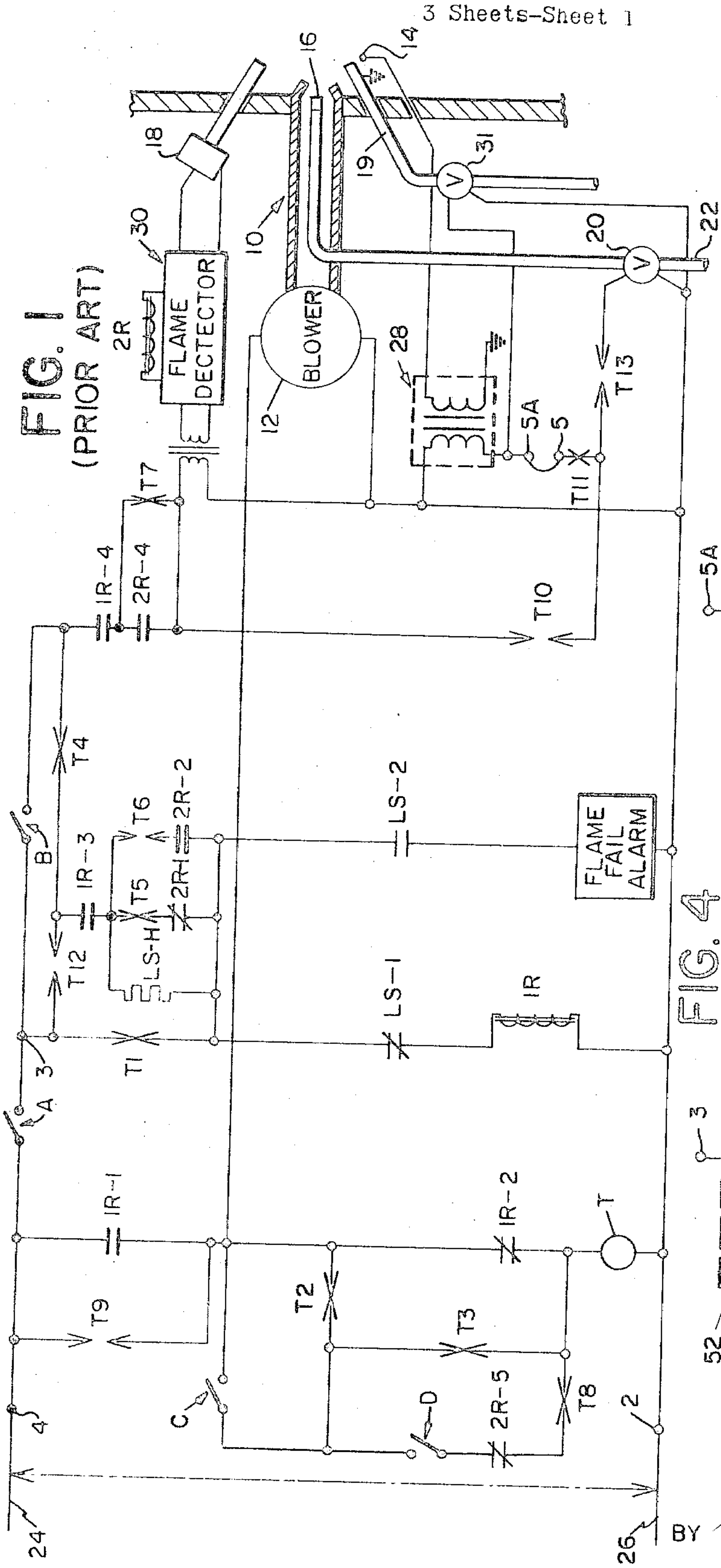
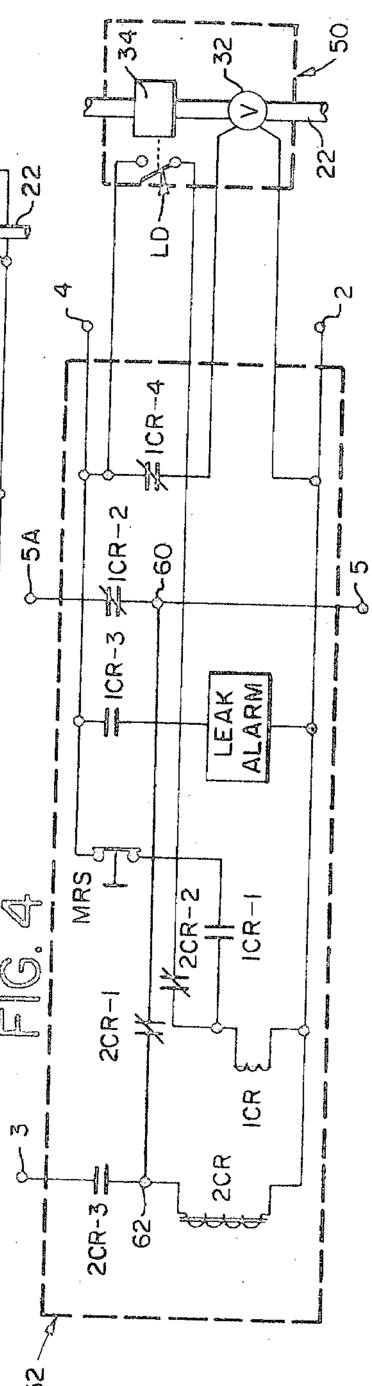


FIG. 4



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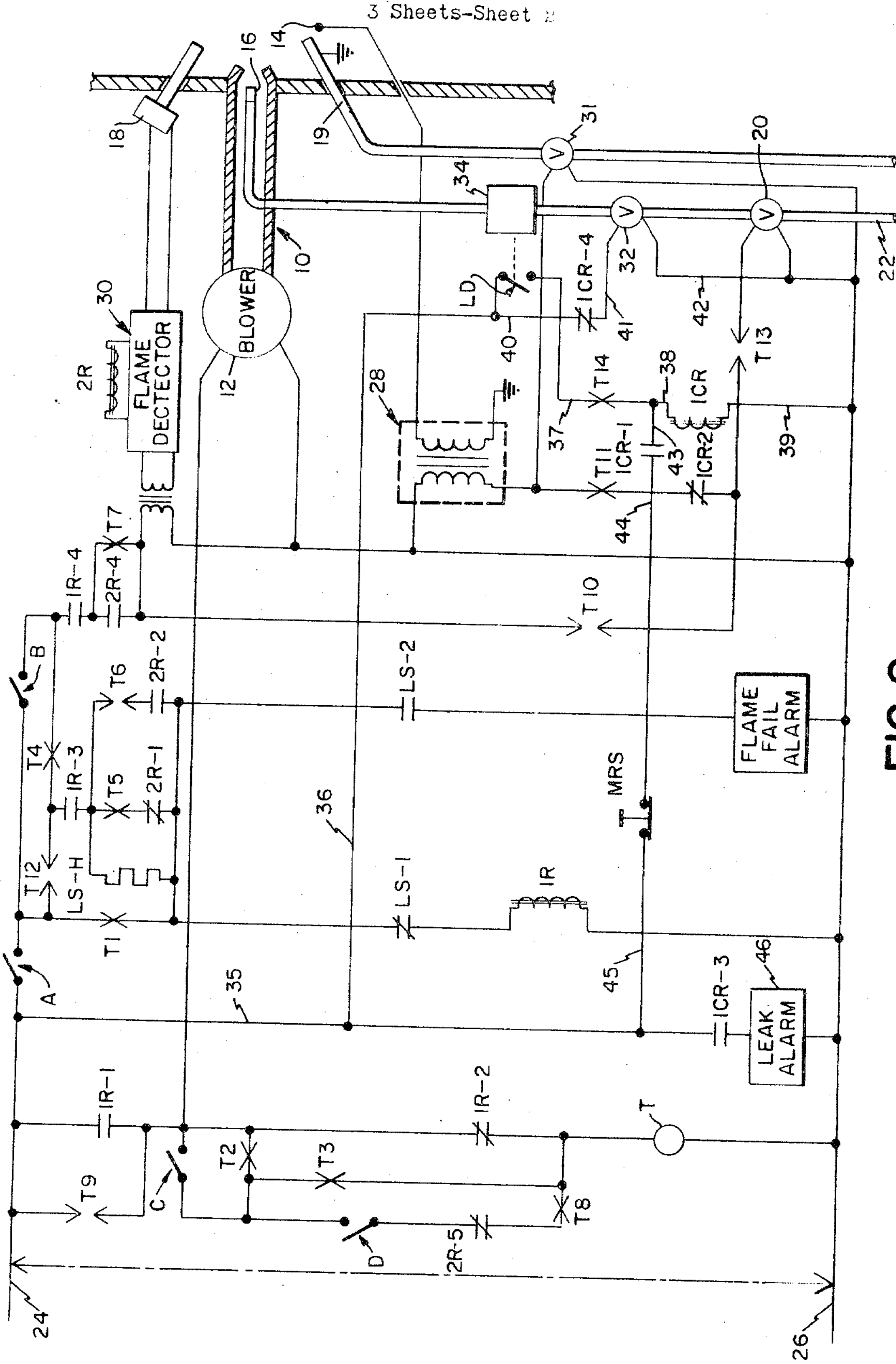
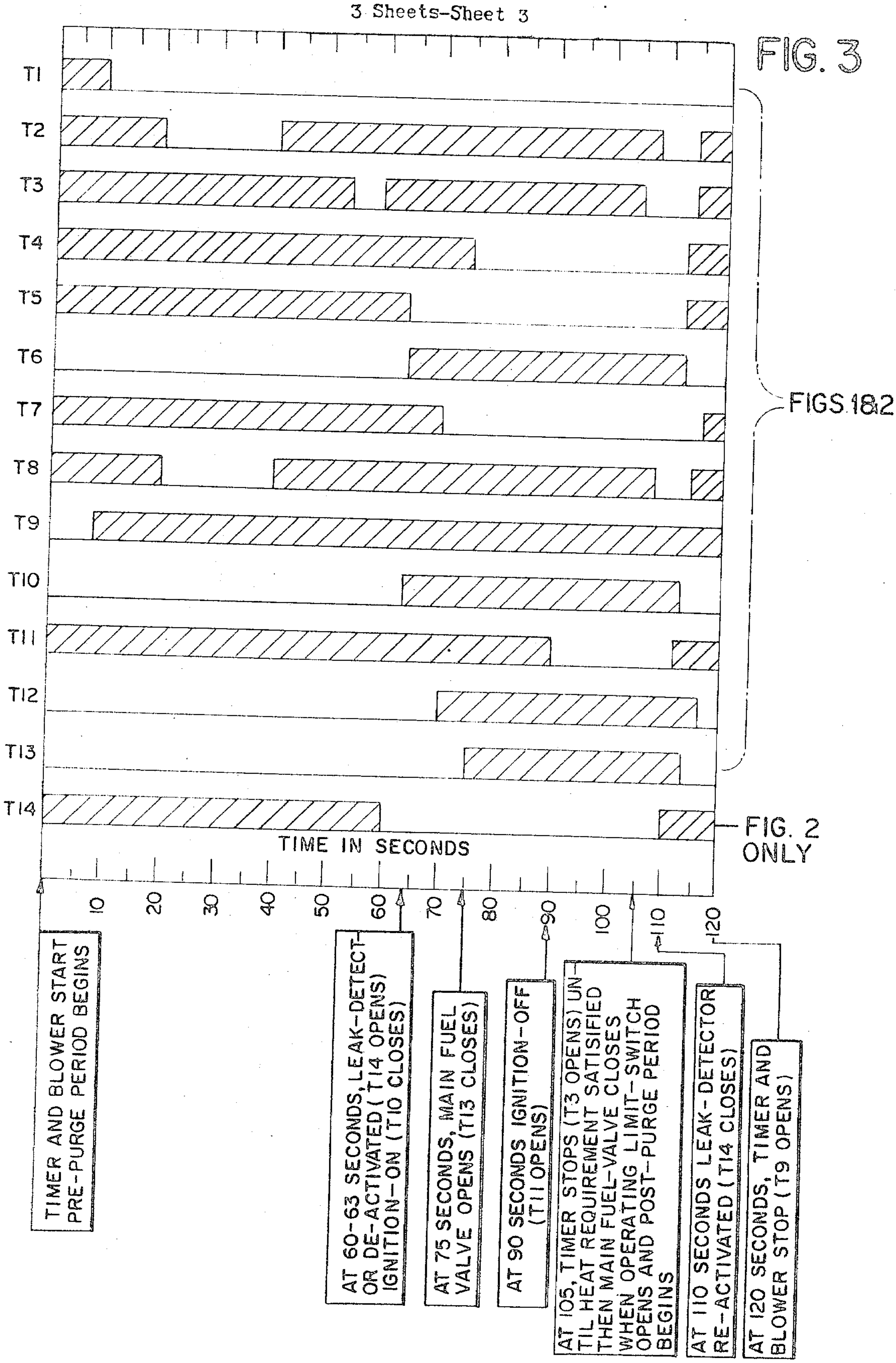

FLAME DECTECTOR
BLOWER
FLAME FAIL ALARM
LEAK ALARM
MRS
LS-1
LS-2
LS-H
IR
ICR
2R
LD

FIG. 2

FIG. 3


T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T13
T14
FIGS. 1&2
FIG. 2 ONLY
TIME IN SECONDS
10
20
30
40
50
60
70
80
90
100
110
120
TIMER AND BLOWER START PRE-PURGE PERIOD BEGINS
AT 60-63 SECONDS, LEAK-DETECTOR DE-ACTIVATED (T14 OPENS) IGNITION-ON (T10 CLOSES)
AT 75 SECONDS, MAIN FUEL VALVE OPENS (T13 CLOSES)
AT 90 SECONDS IGNITION-OFF (T11 OPENS)
AT 105, TIMER STOPS (T3 OPENS) UNTIL HEAT REQUIREMENT SATISIFIED THEN MAIN FUEL-VALVE CLOSES WHEN OPERATING LIMIT-SWITCH OPENS AND POST-PURGE PERIOD BEGINS
AT 110 SECONDS LEAK-DETECTOR RE-ACTIVATED (T14 CLOSES)
AT 120 SECONDS, TIMER AND BLOWER STOP (T9 OPENS)

FUEL-LEAK DETECTOR AND SAFETY SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates to control systems for fully automatic fuel burners of various kinds, including gas and oil burners for furnaces and boilers, and it relates more particularly to safety devices for preventing leakage of fuel through the burner when it is not lighted.

In automatic commercial and industrial heating systems, the intermittent operation of the burner usually takes place with no-one in attendance at all. Consequently, if the main fuel-valve leaks or does not function properly when the burner should be off, fuel will leak through the burner nozzle into the combustion chamber of the furnace, heater or the like. Leakages of this kind occur most often in installations where the fuel to be burned is continuously supplied under pressure to the main fuel-valve. However, they can also occur in installations which have long pre- and post- ignition cycles during which the fuel pump is running for a considerable length of time while the main valve is closed. The resulting danger of exploding the fuel in the furnace when normal ignition takes place has been a long-standing problem in The heating industry. A potentially explosive amount of unburned fuel can readily accumulate in the combustion chamber if fuel leaks through the main fuel-valve while the burner is in a standby condition, or during only the start-up and shut-down portions of the burner cycle.

The imminence of the danger is punctuated by the following quotations from the Jan. 1, 1970 issue of Honeywell "Flame Tips" Vol. 5 No. 6:

"A cubic foot of natural gas (or about ¾ oz. of fuel oil) properly mixed and vaporized and confined, has the explosive equivalent of a stick of dynamite." "A burner firing at full input into a properly designed and sized combustion chamber takes about 8 seconds to fill the chamber. If light-off occurs with the chamber ⅓ or less full (about 2.66 seconds at high fire) the result is a puff. If light-off occurs with the chamber more than ⅓ full, the result is a substantial explosion."

In order to reduce the possibility of an explosion due to accumulation of fuel in the fire box, regulatory authorities for the industry have established certain safety precautions. One such precaution is the requirement that the blower run for a predetermined length of time during the start-up cycle before the ignition source is turned on and the fuel valve opened, in order to try to purge the combustion chamber of fuel before ignition takes place. This is referred to as the pre-purge period. The trend of modern automatic burner control designs has been toward longer pre-purge periods, with the hope of diluting any explosive mixture which may be in the combustion chamber and of flushing so much air through it that all of the combustible mixture will be carried out the stack before ignition takes place. There is, however, a serious difficulty in this approach to the problem, which has not been generally appreciated, but which is nevertheless inherent in it.

For example, if the fuel valve is leaking during the pre-purge period, a large quantity of fuel can be injected into the combustion chamber along with the purging air, thereby increasing, rather than decreasing, the hazard that existed at the start of the pre-purge period. Similarly, if the leak occurs during the post-purge period while the burner is being shut-down upon satisfaction of the requirement for heat, more fuel may be pumped into the combustion chamber during a prolonged post-purge period than during a shorter one. Furthermore, fuel oil that leaks through the burner nozzle during such purge periods impinges or condenses on the walls of the combustion chamber and cannot be flushed out by the air blown through the combustion chamber even during the longest prepurge period that is possible. Consequently, where the fuel valve is leaking, longer purge periods can cause a more disastrous explosion, instead of avoiding one. This is true whether the fuel is natural gas or fuel oil, but more particularly in the case of oil.

It has been proposed heretofore in connection with semi-automatic burners to provide a fuel-leak detector which relies on a continuously burning pilot flame to ignite fuel sensed downstream of the main fuel-valve when the main valve is scheduled to be closed. The resulting flame is detected by a flame detector which then closes an auxiliary valve in the fuel supply line in order to stop the leak. One of the serious disadvantages of such a system is that in order to restart the burner, the standing pilot must be lighted manually before the leak detector is operable, and if the combustion chamber contains a sufficient volume of combustible air-fuel mixture, a disastrous explosion can occur. Furthermore, there is no safeguard against leakage of fuel into the combustion chamber if the standing pilot flames-out, because the leak detector is completely dependent upon the flame detector.

As a practical matter, moreover, such a leak detector is not approved for use by the industry in fully automatic installations, because of its reliance on a standing pilot which is not allowed in unattended (i.e. fully automatic) burner installations. The reasons that standing pilots are not approved for automatic operation are that the fuel leaking into the combustion chamber either is ignited by the pilot and burns, or creates a fuel-rich mixture causing the pilot to flame-out. As pointed out in the United States patent to Brown U.S. Pat. No. 3,223,138, continued burning of the leaked fuel in an unattended system can result in a disastrous overheating of the unit, boiler explosions and the like. Pilot flame-out in an unattended system, on the other hand, can result in equally disastrous consequences if, for example, an attempt is made to relight the burner manually before the combustion chamber is cleared of all fuel. Consequently, standing-pilot burners, in which a pilot flame burns continuously in the combustion chamber of the heating unit, are not approved for fully automatic, unattended systems.

The term "automatic fuel-burner" is used in the present disclosure and claims in the same manner that it is used throughout the industry. Burners or control units that are approved for completely unattended operation for extended periods of time are considered to be automatic. But those which rely on a continuously burning flame or pilot for ignition purposes are not so approved and are therefore not considered automatic.

In industrial installations using heavy Bunker C fuel oil, the fuel valve may leak or stick in a partially or fully open position while the burner is unattended, usually during an overnight shut-down. Automatic controls have been designed to prevent ignition of the burner when such a failure occurs, but to my knowledge no provision has ever been made for stopping the flow of fuel oil into the combustion chamber following a fuel-valve failure, in a completely automatic control system. The result is that unburned fuel oil builds up inside the combustion chamber and may even flood the fire box completely. By the time the trouble is discovered, there is in all probability a collosal mess of congealed Bunker C oil, which must be pumped or otherwise removed with great diffulty from the combustion chamber. Not only is this cleaning process time-consuming and expensive, but the resulting downtime of the furnace, and possibly of a whole plant, is extremely costly. It is important to note in this connection that insurance companies do not usually insure against losses due to damaged equipment and downtime unless an explosion takes place. Consequently, the cost of removing fuel-oil from a furnace, cleaning up and reconditioning the burner following fuel-flooding, which is not infrequent, is not paid for by the insurance company. Furthermore, downtime of plant and equipment in such instances cannot be insured against.

There is also the possibility that a smaller, but still potentially explosive, quantity of fuel may leak into the combustion chamber unnoticed during or after an automatic shut-down for one reason or another. Should the attendant then unthinkingly reset the controls in order to restart the burner, ignition of the accumulation of gas or oil in the combustion chamber may occur with disastrous results. Explosions of this kind occur only too often, with serious injury to personnel and destruction of property.

In addition to lengthening the pre-purge and post-purge periods in the burner operating cycle which, however, as indicated hereinbefore may increase, rather than decrease the hazard, other safety devices have been employed with only limited success. For example, dual main fuel-valves are sometimes installed so that if one leaks, the other will still hold. The disadvantage of such a system is that if one of the valves fails, there is no way of knowing that it is not working until the other valve sticks open or leaks. While the length of time for both valves to fail may be longer than where only one is used, the results are just as disastrous when both valves have failed. Furthermore, since both valves open and close together during each burner cycle, there is not even any assurance that one will last any longer than the other.

The hereinbefore-mentioned patent to Brown U.S. Pat. No. 3,223,138 discloses a safety for preventing re-starting of a constantly attended burner when the fuel-valve leaks. In this case, an inaccessible disabling relay is provided for locking out the controls, so that the attendant cannot inadvertently restart the burner, if the fuel-valve is leaking, without first calling his supervisor or a burner maintenance man capable of diagnosing the trouble and repairing or replacing the valve. However, while the safety system of the Brown patent prevents inadvertent start-up of the burner when a potentially dangerous condition exists, it does not take care of the source of the trouble insofar as automatic controls are concerned, namely the continued leakage of fuel into the combustion chamber after the burner has been shut-down. Consequently, the solution provided in this patent is of little value for automatic, or in other words, unattended burner operation.

Thus, if some time elapses after shut-down due to a leaking fuel valve and before the difficulty is discovered, a considerable amount of fuel may have leaked into the fire box by the time the trouble is discovered. The maintenance or servicing crew will accordingly have a back-breaking task of cleaning up the mess, particularly if the fuel is Bunker C oil. It is not surprising, therefore, that the approach to the problem disclosed in the Brown patent has not been adopted in, nor is it applicable to, fully automatic burner controls. Instead, longer pre-purge and post- purge periods have been resorted to by some of the leading burner control manufacturers in the country.

The principal objects of the present invention are to:

1. prevent fuel explosions by attacking the trouble at its source, namely the leaking fuel-valve, by automatically monitoring, detecting and stopping the leak immediately,
2. lock-out the burner controls independently of other safety lock-outs in the system whenever a fuel-leak occurs through the fuel-valve, thereby permitting the blower or forced-draft means to purge the combustion chamber of dangerous quantities of combustible air-fuel gases, and
3. provide a leak-alarm which is actuated only when the fuel-valve leaks or does not close properly, so that the trouble is pin-pointed immediately and can be repaired without having to dismantle and check other possible causes of trouble.

Another important object of the invention is to eliminate the necessity of removing quantities of raw fuel which may flood the combustion space for the burner due to failure of the fuel valve to close. This objective, however, goes hand-in-hand with that of preventing explosions by immediately detecting and stopping the leak through the fuel-valve.

SUMMARY OF THE INVENTION

In general, the invention resides in monitoring the presence of fuel downstream of the main fuel-valve both during standby periods of operation of the burner and during the portions of the burner cycle when the main fuel-valve should be closed, so that if fuel leaks through the ostensibly closed main fuel-valve, a control lock-out will actuate to close an auxiliary fuel valve which stops the leak and at the same time prevents operation of the burner until the faulty valve is repaired or replaced. To this end, a leak-detector, such as a pressure-actuated switch in the controls for the auxiliary valve that is capable of functioning whether or not a source of ignition has been established, is installed with its fuel sensor in the fuel-supply line between the main valve and the burner nozzle. The auxiliary fuel-valve controls include a dicriminator device for nullifying the action of the leak-detector when it senses the flow of fuel during a normal, scheduled opening of the main fuel-valve, thereby ensuring regular operation of the burner while monitoring the system for fuel leaking through the burner when it is not ignited. The discriminator may be a delayed-action relay, a timer switch or any device capable of preventing the closing of the auxiliary fuel-valve and of co-ordinating with the scheduled opening of the main fuel-valve during the burner operating sequence, so that when the leak-detector senses the flow of fuel to the burner upon normal opening of the main valve, the auxiliary fuel-valve does not close and prematurely shut down the burner

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The advantages of the invention will become more apparent from the description hereinafter of certain embodiments of the invention, illustrated in the accompanying drawings, wherein

FIG. 1 is an electro-mechanical schematic view of a fuel-oil burner installation and control system therefor that is more-or-less typical of the prior art;

FIG. 2 is a view similar to FIG. 1, but showing the leak-detector apparatus and controls therefor of the present invention incorporated therein;

FIG. 3 is a bar graph showing the time relationship of the operation of the contacts of a timer which forms part of the control apparatus of FIGS. 1 and 2; and

FIG. 4 is an electro-mechanical schematic view of the leak-detector apparatus and controls of the present invention incorporated in an add-on unit for an existing burner installation, such as that illustrated in FIG. 1.

In the somewhat simplified oil-burner installation of the prior art illustrated in FIG. 1, the burner 10 has the usual blower 12, ignition electrode 14, burner nozzle 16, flame-detecting photo-electric cell 18 and gas-pilot burner 19. Oil is continuously supplied under pressure to a main fuel-valve 20 through a supply line 22. The switch contacts in the control and power circuits are shown in the positions assumed when the burner is shut down with its operating limit-switch A, running interlock-switch B, airflow-purge interlock-switch C and starting-ignition interlock-switch D, all in the open position. Electrical power is supplied to terminals 2 and 4 across the "hot" feed line 24 and ground 26 from a suitable power source such as a 120 volt A.C. supply. On closing the operating limit-switch A preliminary to automatic operation of burner 10, a master relay 1R is energized through a pair of normally closed lockout-switch contacts LS-1 and initially closed contacts T1 of a sequencer or timer T.

Reference should also be made to the bar graph of FIG. 3 showing a detailed sequence of operations carried out by timer T during each burner cycle, commencing with the closing of the operating limit-switch A through shut-down of the burner following satisfaction of the requirement for heat. Energization of relay 1R closes contacts 1R-1 in a power circuit to the burner blower 12 for starting the pre-purge period. Closing of contacts 1R-1 also completes a circuit through initially closed timer contacts T2 and T3 to the timer T, contacts 1R-2 having opened on energization of master relay 1R. Blower 12 and timer T therefore start running immediately. At the same time contacts 1R-3 and 1R-4 both close. Contacts 1R-3 are located in the lockout circuit of a safety-switch having a heater LS-H, energization of which opens contacts LS-1. Contacts 1R-4 are located in the power line to an ignition transformer 28, main fuel-valve 20, a flame-detector 30 and a shut-off valve 31 for the gas pilot 19.

On closing of the running interlock-switch B, a holding circuit is established for the master relay 1R through initially closed timer contacts T4 and T5, closed relay contacts 1R-3 and a set of initially closed relay contacts 2R-1 of a relay 2R in the flame-detector system 30. Consequently, even though timer contacts T1 open shortly after timer T starts, master relay 1R holds in. Contacts 2R-1 are closed when its relay 2R is not energized and are open when relay 2R is energized, the reverse being true of contacts 2R-2 in an alternate circuit through initially open timer contacts T6. If the flame-detector relay 2R holds in during the pre-ignition period, or if it is de-energized for a period of about one minute after ignition because of ignition or flame failure, lockout-switch heater LS-H will trip out its contacts LS-1. This in turn de-energizes master relay 1R, opening the circuits through relay contacts 1R-4, including the main fuel-valve 20, which shuts down the burner. At the same time a flame-failure alarm circuit is energized on closing of another set of contacts LS-2 which are actuated simultaneously with contacts LS-1 when heater LS-H is energized for a prolonged period of about sixty seconds. Lockout-switch contacts LS-1 and LS-2 do not automatically release from their safey positions when they have been tripped and must be reset manually after heater LS-H has cooled. The burner is therefore locked out until it is manually restarted again.

On the other hand, provided flame-detector relay 2R does not hold in during the pre-ignition period when the flame-detector is energized through initially closed timer contacts T7, the master relay 1R is kept energized by its holding circuit through relay contacts 2R-1, or if need be for a brief time through heater LS-H. Power for the blower 12 and the control circuit for timer T is therefore assured through contacts 1R-1, even during the short period at the start of the burner cycle when timer contacts T9 are open. Nevertheless, timer T stops when its contacts T2 open after about 20 seconds into the cycle, but restarts again when purge interlock-switch C closes following indication of a satisfactory purge. At about 53 seconds into a cycle, timer contacts T3 open, and timer T again stops until the ignition-starting, interlock-switch D closes and provides an alternate circuit through a set of flame-detector contacts 2R-5 and timer contacts T8. During the normal start-up, flame-detector relay 2R will not be energized at the time contacts T3 open. Contacts 2R-5 are therefore usually closed when interlock-switch D closes, so that timer T will restart in order to advance the burner cycle.

It will also be noted that if a flame-failure lockout occurs, timer T automatically recycles itself, due to the fact that contacts 1R-2 close, completing the timer circuit through timer contacts T9 which, as will be seen in the timer bar graph of FIG. 3, closed almost immediately after timer T started and do not open until the end of the cycle. Contacts T9, therefore, provide a holding circuit for the timer, permitting it to recycle when the master relay 1R is de-energized for any reason.

Assuming that all the switches A through D close and that lockout does not occur, contacts T10 close to energize the ignition circuit about 1 minute after the start of the cycle, thereby completing a circuit from the before-mentioned timer contacts T7 through timer contacts T11 to the primary winding of ignition transformer 28. Another circuit is also completed on closing of timer contacts T10 through a shut-off valve 31 in the gas line to the pilot 19, thereby turning on the gas simultaneously with energization of electrode 14. On establishment of a pilot flame, timer contacts T13 close in order to energize the solenoid of main fuel-valve 20, which thereupon opens. If a flame-out occurs, flame-detector relay 2R becomes de-energized, reversing its contacts 2R-1 and 2R-2, which in turn energizes heater LS-H due to the fact that timer contacts T5 opened at the same time that contacts T10 closed. However, if a flame is established and barring some other malfunction, the burner continues to operate until the demand for heat is satisfied. During the portion of the ignition period between the ignition of the gas-pilot **19** and the establishment of a flame following opening of the fuel-valve **20,** power to the master relay **1R** is maintained without energizing heater LS-H by a circuit through timer contacts **T6** which close at the same time that the igniter is energized. In a normal start-up, timer T will stop running temporarily when its contacts T3 open following establishment of the flame. The burner continues to run, however, as long as heat is called for and as long as the flame does not fail.

Upon satisfaction of the demand for heat, operating limit-switch A opens, de-energizing master relay **1R** and closing main fuel-valve **20,** thereby extinguishing the flame. De-energization of relay 1R also closes the contacts **1R-2,** completing a circuit through timer contacts **T9,** in order to restart timer T. The burner blower **12** continues to run through a post-purge period of about 15 seconds until timer contacts **T9** open at the end of the timer cycle. Timer T also stops with the opening of its contacts **T9,** and the system is ready to start-up automatically when heat is again called for. The master control system shown schematically in FIG. **1** and the portion of the timing sequence therefor shown in FIG. **3** are simplified versions of those employed by Electronics Corporation of America in their control systems designated "FIREYE System FP-2 Using Type 26RJ8 Model 6070" and described in their company Bulletin CP–59.

Referring now to FIG. **2,** which shows a control system that is identical with that of FIG. **1** except that it is modified to incoporate the fuel-leak safety of the present invention, an auxiliary fuel-valve **32** is installed at the burner **10** in tandem with the main fuel-valve **20,** and a leak-detector **34** is installed in the fuel line **22** to burner nozzle **16** downstream of main fuel-valve **20.** The auxiliary fuel-valve is desirably a motorized type having a motor actuator for opening the valve when power is supplied to it and having a quick-closing spring action, thereby ensuring rapid closing of the valve when its actuator is de-energized. The leak-detector **34** is shown diagrammatically to represent a pressure switch having a set of mechanically actuated contacts LD, which are connected to the power line **24** ahead of the operating limit-switch A by means of conductors **35** and **36,** and to ground **26** by means of conductors **37, 38** and **39.** Conductor **37** connects one of the leak-detector contacts LD to one side of a spare set of contacts **T14** of timer T, which may be conveniently employed as a discriminator for the purpose of nullifying the action of the leak-detector during the period of the burner operating cycle when the main fuel-valve **20** is open. Conductor **38** connects the other side of contacts **T14** to a control relay **1CR,** which in turn is connected to ground **26** by conductor **39.** Leak-detector contacts LD are normally open, closing when fuel is detected downstream of main fuel-valve **20.**

Auxiliary fuel-valve **32** is connected to the power line **24** ahead of the operating limit-switch A by means of conductors **35, 36, 40** and **41,** and to ground **26** by a conductor **42** common to both the fuel-valves. It will be noted that by connecting both the leak-detector **34** and auxiliary fuel-valve **32** ahead of the operating controls, these units are operable both during the burner-operating cycles and while the burner is in a stand-by condition. A holding circuit, that includes conductors **43, 44** and **45,** provides an alternate circuit for control relay **1CR** from conductors **35** and has a manual reset switch MRS between conductors **44** and **45** for momentarily opening this holding circuit in order to deenergize control relay **1CR.** In addition, a leak-alarm **46** is connected from conductor **35** to the ground **26.**

Leak-detector control relay **1CR** has four sets of contacts as follows:

1CR-1 are located in the holding circuit for control relay **1CR** between conductors **43** and **44,** and are open when **1CR** is de-energized;

1CR-2 are interposed in the ignition-transformer circuit between timer contact **T10** and **T11** and are closed when **1CR** is de-energized;

1CR-3 are located in the leak-alarm circuit and are open when **1CR** is de-energized; and

1CR-4 are located in the auxiliary fuel-valve circuit between conductors **40** and **41** and are closed when **1CR** is de-energized.

It will be noted from FIG. **3** that the timer contacts **T14** are closed at the start of the timing cycle, open shortly before the ignition transformer **28** is energized by the closing of contacts **T10,** and close shortly after the main fuel-valve **20** closes on de-energization of the master control relay **1R** when operating control-switch A opens upon satisfaction of the requirement for heat. As will become more apparent hereinafter, timer contacts **T14** discriminate between the times when the leak-detector system should, and should not, function to shutdown or prevent operation of the burner. It will also be apparent that as long as leak-detector contacts **1CR-4** are closed, auxiliary fuel-valve **32** is energized and is therefore open, whether of not the operating control is calling for heat.

Operation of the leak-detector system shown in FIG. **2** as a built-in part of the burner control system is as follows. If the main fuel-valve **20** leaks during a standby period when the burner is not running, lead-detector **34** senses the oil that leaks through the main fuel-valve **20,** and its contacts LD close. Since the discriminator contacts **T14** remain closed throughout the standby period of the burner, the leak-detector circuit through control relay **1CR** is completed upon closing of contacts LD, thereby immediately energizing control relay **1CR** even though the burner is in a standby condition not actually running. Consequently, all four sets of contacts of control relay **1CR** reverse their conditions, including **1CR-4** which open in order to de-energize the auxiliary fuel-valve circuit, thereby closing auxiliary fuel-valve **32.** The leak is accordingly immediately stopped, preventing the accumulation during standby of unburned fuel in the fire box of the furnace or boiler. At the same time that auxiliary valve **32** closes, the leak-alarm circuit is energized by the closing of contacts **1CR-3,** immediately signalling the attendant while the burner is still in standby condition that the main fuel-valve is not functioning properly and that it should be checked and serviced.

If, on the other hand, no-one is on the premises at the time a leak occurs, or if the leak-alarm goes unnoticed until there is a call for heat, the burner will start its operating cycle in the usual manner when operating limit-switch A closes. Timer T will start to run as usual and will automatically sequence the start-up operations to the point at which the ignition circuit is to be energized by the closing of timer contacts **T10.** However, when contacts **T10** close, the ignition circuit through transformer **28** is not completed because the leak-detector control-relay contacts **1CR-2** are open due to energization of 1CR upon actuation of leak-detector **34** in response to the presence of fuel downstream of main fuel-valve **20**. Consequently, there is no ignition spark at electrode **14**, the gas-pilot valve **19** does not ignite and the burner controls are locked-out by the flame-detector system, which in this instance is the same as that shown in FIG. **1**. Thus, since flame-detector relay contacts 2R-2 are open due to the fact that relay 2R is not energized when the flame fails, heater LS-H becomes energized when timer contacts T5 open simultaneously with the closing of contacts T**10**. Heater LS-H will then remain continuously energized long enough to trip its lock-out switch LS-**1**, thereby de-energizing master relay 1R and opening contacts **1**R-**1**, **1**R-3 and **1**R-**4**. There is accordingly no possibility of light-off or even of energizing the ignition transformer, following detection of a leak, and the potential danger of igniting a residue of combustible fuel in the fire box is eliminated.

It will be noted that contact 1CR-1 in the holding circuit for control relay 1CR close when 1CR is energized. Control relay 1CR, therefore, remains energized until the holding circuit is broken by manual opening of the reset switch MRS. A second and completely independent lock-out of the controls is therefore provided by the leak-detector safety system of the present invention. It should also be noted that the leak-detector system will operate both during the pre-purge period and post-purge period of the burner operating cycle, as well as during the standby condition of the burner just described. However, in order to prevent the leak-detector 34 from interfering with the normal operation of the burner, it is necessary to nullify its action during the portion of the burner-operating cycle when the main fuel-valve **20** should be open.

Thus, under normal operating conditions of the burner, the discriminator-timer contacts **T14** open a few seconds (see FIG. **3**) before the ignition tranformer 28 is energized, thereby preventing leak-detector contacts LD from completing the circuit through control relay 1CR when main fuel-valve **20** opens. If desired, however, contact T14 may be set to open simultaneously with energization of the igniter, or in some installations just prior to the opening of the main fuel-valve. Upon closing of discriminator-timer contacts T14 seconds after main fuel-valve **20** closes on shutdown, the action of leak-detector **34** becomes effective again in detecting and signalling the presence of fuel downstream of the main fuel-valve **20** during th post-purge period of operation of the burner. Should the main fuel-valve not close properly, the auxiliary fuel-valve immediately closes automatically to stop the leakage of fuel into the firebox, and the leak alarm is actuated so as to call attention to the trouble. Moreover, as mentioned hereinbefore, the burner is in effect locked-out against automatic operation on the next call for heat, but will nevertheless begin its start-up program through the prepurge period before being completely locked-out by the flame-fail safety. Under no circumstances is fuel permitted to pass downstream of the main valve while it is closed without closing the auxiliary fuel valve and simultaneously actuating a leak alarm. Furthermore, detection of undesired fuel downstream of the main valve actuates the auxiliary valve independently of the main valve to prevent prolonged leakage of fuel into the fire box while the burner is not lit.

LEAK-DETECTOR ADD-ON UNIT OF FIG. 4

Reference is now had more particularly to the modification of the invention shown in FIG. 4, which illustrates an add-on unit for providing the leak-detector apparatus and control of the present invention in existing burner installations. For convenience the same reference characters are employed in designating mechanical and electrical components of the modification shown in FIG. 4 that are identical with those used in the control system of FIG. **2**. The add-on unit consists of an auxiliary valve and leak-detector, pressure-switch assembly **50**, and an add-on control panel **52**, the assembly **50** being constructed so that it can be readily installed in the fuel supply line **22** (FIG. **1**) downstream of main fuel-valve **20** of the existing installation. If miniturized electronic components are employed, the add-on control panel 52 may be mounted directly on the assembly **50**, forming a self-contained unit therewith. However, panel 52 can also be installed at the existing master control panel for the burner, in which case suitable terminals should be provided at the add-on panel for the auxiliary fuel-valve 32 and leak-detector 34, in addition to those shown in FIG. 4 for connecting the unit to the master controls.

For the most part, installation of the add-on controls with the master controls for an existing burner is simply a matter of making electrical connections from existing terminals at the master control panel to corresponding terminals provided on the leak-detector, add-on panel **52**. As shown in FIG. 1 most burner control panels are provided of the terminal marked 2 located in the ground **26** and another marked 4 located in the power supply line **24**. A terminal marked 3 is also usually available on the load side of the operating-control switch A. In some installations additional terminals may be available, making it unnecessary to break into an existing circuit in order to make the connections required for the leak-detector add-on unit of the present invention. For purposes of the present illustration, however, FIG. 1 shows a jumper wire from points marked 5 and 5A in the conductor to the ignition transformer 28, where two fo he connections for the add-on unit can be made.

The add-on control panel 52 should therefore be provided with correspondingly numbered terminals 2, 3, 4, 5, and 5A, which can be connected to the corresponding terminals shown in FIG. 1, in order to interpose the leak-detector safety system shown in FIG. 4 into the existing master control system. As in the system shown in FIG. 2, the auxiliary valve 32 is opened on energization of its control circuit from terminal 4 through control-relay contacts 1CR-4 of control-relay 1CR. In this instance, however, 1CR is located on the add-on panel **52**. Contacts 1CR-4 are initially closed and open on energization of control-relay 1CR to de-energize the auxiliary fuel-valve circuit and close the auxiliary valve 32. Control relay 1CR is located in the leak-detector circuit through the contacts LD of leak-detector 34 from terminal 4 to the ground terminal 2. Control-relay 1CR again has contacts 1CR-1, 1CR-2, and 1CR-3, which function in the same manner as in the system of FIG. 2.

While the add-on unit could be arranged to employ a spare set of contacts in the timer T of the master control system for isolating the leak-detector circuit while the main fuel-valve 20 is open during a normal burner-operating cycle, such timer contacts may not always be available in the existing installation. Therefore, in order to make it applicable in various different burner-control systems, the leak-detector add-on unit shown in FIG. 4 is provided, by way of example, with a somewhat different discriminating system from that employed in the system of FIG. 2. Thus, a discriminator relay 2CR is located in a circuit that is energized on energization of the ignition transformer, its initially closed contacts 2CR-2 being located in the leak-detector circuit and opening with energization of relay 2CR in order to prevent energization of leak-detector relay 1CR during the period when the fuel valve is scheduled to be open. As indicated hereinbefore terminals 5 and 5A of the add-on panel 52 are connected at points 5 and 5A, respectively, in the ignition circuit of the existing controls (FIG. 1), the jumper wire shown in FIG. 1 of course being discarded when the connections for the add-on unit are made. Contacts 1CR-2 of leak-detector relay 1CR are disposed in a circuit 5-5A of the add-on unit between terminals 5 and 5A so that when 1CR is energized 1CR-2 opens to interrupt the circuit to ignition transformer 28. Discrimination control-relay 2CR is connected in parallel with the igniter in a circuit from a point 60 in the circuit 5-5A through a point 62 to ground terminal 2, so that whenever power is supplied to the igniter, control-relay 2CR is energized.

Contacts 2CR-2 of the dicriminator relay are located between contacts LD and the leak-detector control-relay 1CR, such that when relay 2CR pulls in, contacts 2CR-2 open, preventing energization of leak-detector relay 1CR. Discriminator relay 2CR is also provided with initially closed contacts 2CR-1 in the discriminator circuit from terminal 5 between points 60 and 62, as well as with initially open contacts 2CR-3 in a holding circuit through terminal 3, which is connected to the corresponding terminal of the master control system after operating limit-switch A (FIG. 1). On energization of relay 2CR, contacts 2CR-1 open, and simultaneously therewith contacts 2CR-3 close to hold-in relay 2CR until operating switch A opens on satisfaction of the call for heat.

It is apparent from the foregoing that when timer switch T10 closes during a normal startup of the burner, the ignition transformer 28 is energized in the conventional manner described hereinbefore in connection with the prior art controls shown in FIG. 1. However, with installation of the leak-detector add-on unit of the present invention, power for the igniter is provided through control-relay contacts 1CR-2 in the circuit 5-5A of the add-on panel 52. Consequently, when terminal 5 is energized, discriminator relay 2CR also becomes energized, opening discriminator contacts 2CR-2 in the leak-detector circuit prior to opening of main fuel-valve 20 when timer contacts T13 close. The leak-detector relay 1CR, therefore, does not become energized when contacts LD close on activation of leak-detector 34 by the normal flow of fuel downstream of the main valve. The burner will accordingly light-off in the usual manner and continue to burn as long as operating limit-switch A holds in.

It will be noted, moreover, that even though the igniter is de-energized following establishment of a flame by the burner 10, discriminator relay 2CR is held in throughout the burn by the closing of its contacts 2CR-3, thereby preventing closing of the auxiliary fuel-valve 32 during normal operation of the burner. On satisfaction of the heat requirement, operating limit-switch A opens closing main fuel-valve 20 and de-energizing terminal 3. Discriminator relay 2CR, therefore, drops out, permitting leak-detector 34 to again monitor the presence of fuel downstream of main valve 20. Leak-detector contacts LD in the meantime will have opened, provided of course that main fuel-valve 20 closes properly when operating limit-switch A opens, so that control-relay 1CR is not energized when contacts 2CR-2 close.

If, however, the main fuel-valve 20 does not close, contacts LD of leak-detector 34 do not open, so that control-relay 1CR is energized immediately upon the closing of discriminator contacts 2CR-2. The leak-detector controls then take over as described in connection with the system shown in FIG. 2 to close auxiliary fuel-valve 32 when contacts 1CR-4 open. The leak-detector contacts 1CR-2, which are located in the ignition circuit 5–5A of the add-on panel, likewise open when 1CR pulls in, so that ignition cannot take place. Contacts 1CR-3 of the leak-detector relay 1CR also close in order to set-off a leak alarm, while contacts 1CR-1 close to complete a holding circuit for relay 1CR directly from power terminal 4. The burner controls are then in effect locked-out and can only be reset by manually opening reset switch MRS in the holding circuit for relay 1CR, in order to let it drop out.

Similarly, during a standby period of the burner while operating limit-switch A is open, power is supplied to auxiliary fuel-valve 32 from terminal 4 through closed contacts 1CR-4 to ground at terminal 2. Auxiliary fuel-valve 32 therefore remains open as long as contacts 1CR-4 are closed. Since contacts LD in the leak-detector are open when fuel is not present downstream of the main fuel-valve 20 — this course being the normal condition during such intermittent standby periods when the burner is not firing — control-relay 1CR is not energized, and the burner controls function normally as hereinbefore described. However, if the main valve 20 leaks during standby, fuel will be detected by leak-detector 34, which will close contacts LD completing the leak-detector circuit from terminal 4 through closed contacts 2CR-2 and control relay 1CR to ground at terminal 2. Control-relay 1CR is therefore energized, opening contacts 1CR-4 in the auxiliary fuel-valve circuit, which in turn deenergizes auxiliary fuel-valve 32, causing it to close and stopping the fuel leak through the main valve.

Energization of control-relay 1CR again closes contacts 1CR-1 in its holding circuit and also closes contacts 1CR-3 in the leak-alarm circuit in order to signal attention to the fuel leak and to trouble with the main fuel-valve. At the same time, energization of 1CR opens contacts 1CR-2 in the ignition circuit through terminals 5 and 5A, so that if heat is called for before the leak alarm is noticed, ignition cannot take place and the burner controls lock-out as before. On the other hand, if the leak-detector is actuated while the burner is in the pre-purge period of its operating cycle, the controls will again lock-out after progressing to the point just prior to ignition. Thus, whether the leak occurs during a purge period or when the burner is in a standby condition, the auxiliary fuel-valve is closed immediately upon detection of the leak, but lock-out of the burner controls does not occur until the cycle progresses to the point just before the igniter is energized. Consequently, the fuel leak is stopped immediately, but the blower will run through all or part of the pre-purge period, in order to flush or dilute unburned fuel, especially vaporized oil or gas, that may have been collected in the combustion chamber from the leaking main fuel-valve.

While the leak-detector is nullified by the discriminator just prior to ignition in both embodiments of the invention herein disclosed in **FIGS. 2** and **4**, it will be apparent that this could occur just prior to the opening of the main fuel-valve, because in both these systems pre-ignition is provided by the gas pilot-burner **19.** However, in the case of the add-on unit of **FIG. 4** at least, it is desirable to energize the discriminator relay **2CR** on energization of the igniter because it can then be used on systems having simultaneous ignition and fuel, as well as on those having pre-ignition. Furthermore, it could be dangerous to permit the pilot-burner to ignite if the main fuel-valve has not been operating properly. It is also doubtful whether the advantages of keeping the leak-detector operative until the instant the main fuel-valve opens would be worth the additional expense involved in the add-on unit, at least.

It will also be appreciated that numerous devices can be employed for nullifying the action of the leak-detector, other than those shown in **FIGS. 2** and **4.** For example, a time-delay relay can be used in place of timer contacts **T14** (**FIG. 2.**) or discriminator relay **2CR** (**FIG. 4**). A suitable time-delay relay switch of conventional design could be wired so that it is energized on closing of operating limit-switch A, but having its switch contacts set to delay opening of the leak-detector circuit until the point in the burner start-up just before the igniter or main fuel-valve are energized. The leak-detector would therefore be operative for monitoring the system for fuel leakage up to the point where the time-delay relay contacts open just before combustion takes place. Opening of the operating limit-switch A on shutdown would then de-energize the time-delay relay and reset the leak-detector system for again monitoring fuel leakage during and following the burner shutdown cycle.

What is claimed is:

1. In an automatic fuel-burner system having a fuel-supply line, a main fuel-valve in said fuel-supplying line for controlling the flow of fuel to the burner, a fuel igniter for initiating a flame in a combustion chamber during each operating cycle of the fuel-burner system and operating controls for said system having means for sequencing the operating cycle and for opening said main fuel-valve during scheduled periods in said operating cycle with the portion of said fuel-supply line upstream of said main fuel-valve under constant fuel-pressure, a fuel-leak detector and safety system comprising in combination

an auxiliary fuel-valve in said fuel-supply line in tandem with said main fuel-valve,

a leak-detector in said fuel-supply line downstream of said main fuel-valve operable for sensing fuel leaked by said main fuel-valve both before and after the source of ignition is established,

control means for closing said auxiliary fuel-valve in response to the action of said leak-detector on sensing fuel in said supply-line downstream of said main fuel-valve, said control means being connected to said burner-operating controls independently of said main fuel-valve, and

discriminator means for nullifying the action of said leak-detector on said control means for said auxiliary valve during the scheduled periods when said main fuel-valve is open, such that said auxiliary fuel-valve remains open during said scheduled periods.

2. A fuel-leak detector and safety system as defined in claim **1,** wherein

said auxiliary fuel-valve is provided with electromechanical actuating means in a first control circuit connected to a source of power independently of the controls for said main fuel-valve,

said control means for closing said auxiliary fuel-valve comprising a switching device in a second control circuit with said leak-detector connected to the power source independently of said main-fuel valve controls,

said leak-detector comprising a fuel-sensitive switch in said second circuit arranged to close in response to the presence of fuel in said fuel-supply line downstream of said main fuel-valve,

said switching device having a first set of switch contacts in said first control circuit for closing said auxiliary fuel-valve,

said discriminator means comprising a set of normally closed timer contacts in said second control circuit co-ordinated with said sequencing means to open prior to said scheduled periods and to close following said scheduled periods, and

a lock-out device including a second set of switch contacts of said switching device in a holding circuit therefor connected to said power source independently of said burner-operating controls.

3. A fuel-leak detector and safety system as defined in claim **1,** which further includes ignition disabling means responsive to said leak-detector and connected in series with said fuel igniter for preventing operation thereof when fuel is sensed by said leakdetector, said discriminator means being also effective in de-activating said ignition-disabling means during such scheduled periods.

4. The combination defined in claim **1,** wherein said fuel-burner system is provided with conventional alarm systems including a flame-failure alarm and said fuel-leak detector and safety system includes a leak-alarm which is activated completely independently of said conventional alarm systems in response to the action of said leak-detector on sensing fuel downstream of said main fuel-valve, said discriminator means having provision for nullifying the action of said leak-detector on said leak-alarm during said scheduled periods.

5. The combination defined in claim **1,** wherein said fuel-burner system includes an electrically powered fuel igniter and said burner-operating controls are provided with an ignition circuit for supplying electrical energy to said fuel igniter, as well as with conventional alarm systems including a flame-failure alarm and said fuel-leak detector and safety system includes an ignition-disabling switch for opening said ignition circuit and a leak-alarm, said ignition-disabling switch and leak-alarm being controlled by said leak-detector completely independently of said burner-operating controls and of said conventional alarm system for preventing operation of said igniter and for actuating said leak-alarm, respectively, when fuel is sensed by said leak-detector, said discriminator means having provision for preventing the opening of said ignition circuit and the actuation of said leak-alarm during said scheduled periods when said main fuel-valve is open.

6. A fuel-leak detector and safety system for an existing automatic fuel-burner having a main fuel-valve in a fuel-supply line for controlling the flow of fuel to the burner, a fuel igniter and operating controls for said fuel-burner having means for sequencing the operating cycle of said burner including the scheduled opening of said main fuel-valve at a predetermined point in said cycle, the portion of said fuel-supply line upstream of said main fuel-valve being under constant fuel-pressure, said fuel-leak detector and safety system comprising in combination

an auxiliary fuel-valve for installation in said fuel-supply line in tandem with said main fuel-valve,

a leak-detector for installation in said fuel-supply line downstream of said main fuel-valve and operable for sensing fuel leaked by said main fuel-valve both before and after the source of ignition is established,

control means for closing said auxiliary fuel-valve in response to the action of said leak-detector on sensing fuel in said supply-line downstream of said main fuel-valve, said control means having provision for being operatively connected to said burner-operating controls independently of said main fuel-valve, and

discriminator means for nullifying the action of said leak-detector on said control means during scheduled periods when said main fuel-valve is open, such that said auxiliary fuel-valve remains open during said scheduled periods.

7. A fuel-leak detector and safety system as defined in claim **6**, which further includes ignition-disabling means responsive to said leak-detector for connection in series with the fuel igniter in said automatic fuel-burner and said discriminator means being also effective in de-activating said ignition-disabling means during such scheduled periods.

8. A fuel-leak detector and safety system as defined in claim **7** wherein said auxiliary fuel-valve is provided with electro-mechanical actuating means in a first control circuit capable of being connected to a power source independently of the controls for the main fuel-valve in said fuel-burner, said control means for closing said auxiliary fuel-valve comprising a switching device in a second control circuit with said leak-detector capable of being connected to a power source independently of said main fuel-valve controls, said switching device having a first set of switch contacts in said first circuit for closing said auxiliary fuel-valve.

9. A fuel-leak detector and safety system as defined in claim **8**, wherein said discriminator means comprises switch-means in said second control circuit and means co-ordinated with said scheduled periods when said main fuel-valve is open for opening said switch-means prior to said scheduled periods and for closing said switch-means following said scheduled periods.

10. A fuel-leak detector and safety system as defined in claim **9**, wherein said switch-means comprises a device selected from the group consisting of a timer switch, a control-relay switch and a time-delay relay switch.

11. A fuel-leak detector and safety system as defined in claim **10**, in which said ignition-diabling means comprises a second set of switch contacts of said switching device in the circuit to be connected in series with said fuel igniter, said second control circuit being connected in parallel with said first control circuit.

12. A fuel-leak detector and safety system as defined in claim **11**, which further includes a leak-alarm circuit connected in parallel with said first control circuit, said switching device having a third set of switch contacts in said leak-alarm circuit for de-activating said leak-alarm circuit during said scheduled periods.

13. A fuel-leak detector and safety system as defined in claim **12**, which further includes a holding circuit for said switching device by-passing said leak-detector for locking out the operating controls for said burner, said switching device having a fourth set of said switch contacts in said holding circuit for closing said holding circuit when said switching device is energized and a manual reset switch for de-energizing said holding circuit.

14. A fuel-leak detector and safety system as defined in claim **13**, wherein said auxiliary fuel-valve is open when said electro-mechanical actuating means is energized, said leak-detector comprising a nomally open fuel-sensitive switch which closes on sensing fuel in said fuel supply-line, said switching device comprising a control relay having a plurality of switch contacts comprising said first, second and third sets of switch contacts, said first and second sets of switch contacts being closed when said control relay is de-energized and said third and fourth sets of contacts being open when said control relay is de-energized, all said switch contacts being reversed when said control relay is energized, said discriminator switch means being disposed in said second control circuit between said leak-detector pressure switch and said control relay.

15. A fuel-leak detector and safety system as defined in claim **1**, wherein said fuel-burner system further includes forced-draft means, said control means for closing said auxiliary fuel-valve being also independent of said forced-draft means such that said forced-draft means remains operable for purging combustible fuel-air gases from the combustion chamber.

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