BASIC BURNER EQUIPMENT IS AT THE HEART OF FLAME PROTECTION

Frederick Cowan, combustion specialist, develops a basic approach to a system specification

IN ALL THE MANY discussions of the furnace safeguard problem, no one has yet spelled out the role of the most vital components, the ignitor and the burner. The scanner, or flame sensor, is considered essential here, of course; but it cannot, by any stretch of the imagination, be given primary consideration if we are to maintain any sense of proper precedence.

To begin a specification for a furnace protection system by selecting a flame detector is as inappropriate as commencing with the choice of radar equipment for a bomber which may not even be airworthy. It is probably safe to say that the designer whose first step is selecting his flame detector cannot possibly do his job properly. Nor can he do justice to the detector selected. Why? Simply because the scope of the task required of the flame safeguard device has not been defined. No limits have been set, no field of action spelled out. No mention has yet been made of the responsibilities of other, more basic equipment. How, then, can one say whether the flame detector will do its job; or, in the tragic event of failure, whether it has *done* its job? In a system design that begins like this no one can ever really know where the blame for failure lies. It can truly be said that this approach is unfair to designer, equipment and user alike; that no one benefits, and that, consequently, there must be a better way.

Having established that the problem is of sufficient importance to deserve our best efforts (this point is completely developed in References 1–4 and needs no elaboration here), we should set *first things first,* as our primary design criterion. The *first* things, of course, are the burners that consume the fuel and the ignitors that furnish energy to ignite those burners. When we begin our specification by delineating the functions and limitations of this basic equipment, the reader will find that the flame detector and its functions are automatically specified. We shall see that though its role is of tertiary, rather than primary, importance, it is decidedly a critical and essential one.

Let us begin to develop the specification, therefore, not with the device that acts first or first comes to mind, but with the one which does the most important job—that of burning the fuel. Beginning with a general statement and progressing through the particulars, it becomes obvious how the needs of the primary device form the specification for the secondary device and so on. In this progression, the requirements of the burner determine the functions of the ignitor, the burner and ignitor taken together spell out the specification for the scanner and the interlock system, and all impose inter-acting demands on the control system.

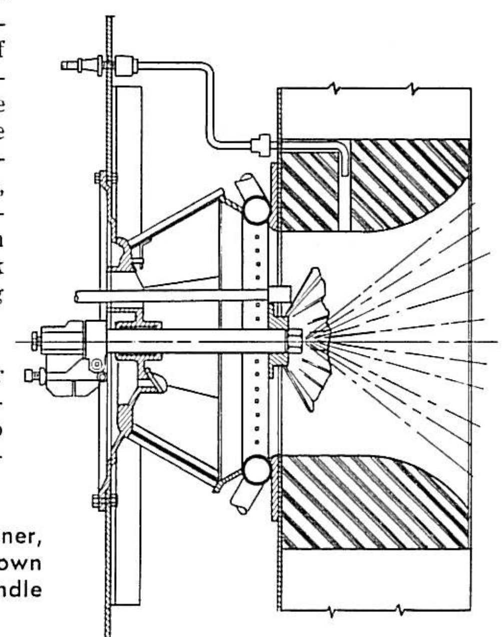
SECTION I. BURNERS. The burner shall be a proven item of equipment with demonstrated ability to safely burn the types and quantities of fuel specified (elsewhere) under the following conditions:

A. Normal burning. After light-off and stabilization of flame the burners shall safely consume all fuel supplied to them through a firing (turndown) range of 8 to 1.

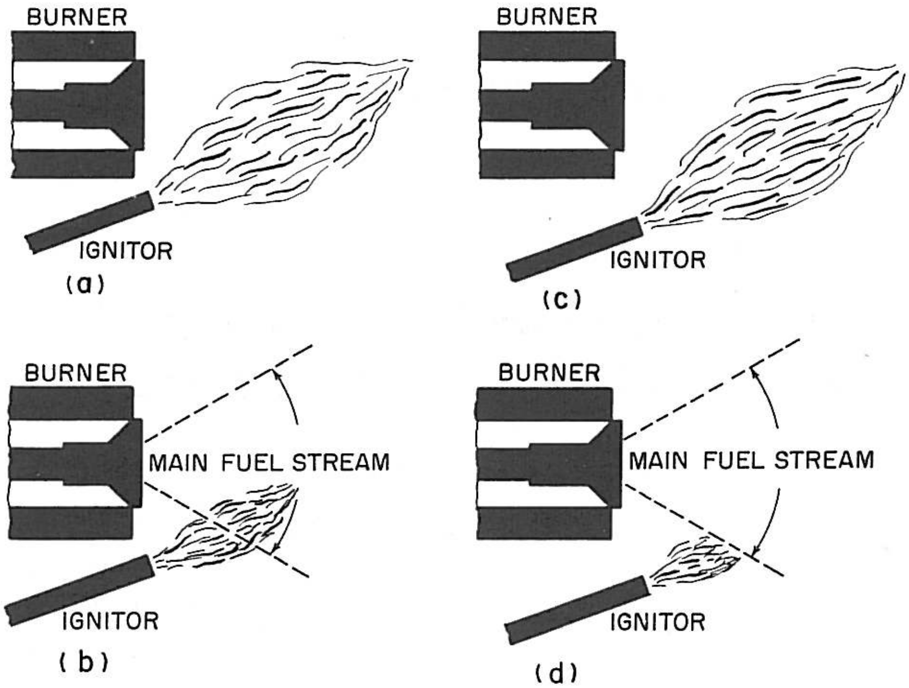
1. Fuel-air ratio. Burners shall operate safely and without evidence of unburned combustibles or instability as long as fuel-air ratio is maintained within limits defined by +5% to +50% excess air. Burner manufacturers shall specify optimum excess air for each fuel at

a. Maximum rating.
b. 50% maximum rating.
c. Minimum rating.

Note: So far the burner specification spells out some basic demands for combustion control and interlock system to keep operating



This integral unit has burner, ignitor and scanner. Scanner shown is a quartz rod-glass fiber bundle



Ignitors must be evaluated rigorously. From (a) to (b) flame is severely reduced by main burner air but still ignites fuel. From (c) to (d) flame becomes useless and hazardous, shortened by main burner air

conditions within the range where the burner can operate properly and practically.

2. Fuel supply conditions. Burners shall operate safely and without evidence of unburned combustibles or instability as long as the following conditions are maintained:

a. Gas supply pressure to the burners shall not be less than —% below burner manufacturer's requirement for minimum rating, nor more than —% above his requirement for maximum rating.

b. BTU content of gas fuel shall be within plus —% and minus —% of specified value.

c. Gas burners shall be capable of operation with air containing —% moisture at minimum rating.

d. Gas burners shall not be subjected to slugs of water or air in fuel supply.

e. Oil supply pressure to burners shall not be less than —% below manufacturer's requirement for minimum rating, nor more than —% above his requirement for maximum rating.

f. Oil temperature at burners shall be maintained within ±— degrees F. of burner manufacturer's requirement for optimum performance.

g. Oil burners shall not be subjected to slugs of air or water in fuel supply.

Note: The foregoing spells out still more requirements of the interlock system—and relieves the flame detector of part of its burden. Coal is not detailed here since space does not permit treatment of the many variables.

3. Mechanical conditions. Burner manufacturer shall specify the limits of mechanical adjustment, wear or other maladjustment within which his burner will meet the conditions specified herein. Limits shall be set forth for the following as applicable:

a. Air register position (for entire load range).
b. Gas and/or oil gun position.
c. Tip-diffuser-throat relationship.
d. Oil tip—possible to assemble improperly? Yes ( ) No ( )
e. Permissible oil tip diameter wear —%.
f. Permissible gas orifice wear —%.
g. Service valve opening.
h. Seal or union leakage critical? To what degree?
i. Other.

Note: This imposes still further requirements on the interlock system and imposes some on the operating personnel.

4. Stability requirements. It is proposed that this system will operate with ignitors (in continuous service), (for light-off and stabilization only). Unless continuous ignitor service is specified the burner manufacturer shall specify the turndown rate at which ignitors are required to maintain stable conditions **for**:

a. oil fuel; — to —
b. gas fuel; — to —

c. Burner manufacturer shall specify maximum load swing which may be taken in — seconds with complete burner stability. The swing specified shall indicate area of load range and direction of swing for most critical condition, (as 25% downward swing from ¼ to minimum load).

Note: If it is possible to use continuous ignitors it is obvious that meeting many of the burner requirements is greatly simplified and the system becomes simpler and less expensive.

5. Ignition requirements:

a. Burner manufacturer shall specify quantity of ignition energy required to successfully ignite each fuel within — seconds under the conditions set forth in Section I-B. Manufacturer shall further specify the point or area at which ignition energy is to be supplied.

b. Burner manufacturer shall specify quantity of ignition energy required to maintain flame stability as required under sections I-A, 1, 2, 3, and 4.

The degree to which our primary problem, the burner, affects the specification for secondary items is becoming very apparent. Yet we have thus far covered only the relatively safe area of service, normal operation. Let's consider specifying burner function at light-off, the period most authorities agree accounts for fully half of all furnace explosions.

SECTION I-B. BURNER LIGHT-OFF. When supplied with ignition energy as defined and specified in Section I-A 5, each burner shall light-off and achieve stability within — seconds under the following conditions:

1. Air flow. Any condition of air flow permissible under the provisions of Section I-A 1.

2. Fuel flow. Any condition of fuel flow permissible under the provisions of Section I-A 2. Normal light-off shall occur at —% of maximum rating.

3. Mechanical conditions. Any condition of mechanical fitness within the limits set forth under Section I-A 3.

Here, in fewer than eighty words, is a tangible, explicit response to the awful truth that 50% of all furnace explosions occur during light-off (which occupies considerably less than 1% of operating time). Other factors are involved in a complete answer, of course. We must prove that no combustibles exist in the furnace prior to light-off. We must prove that air flow during light-off is more than enough to burn fuel leaking into the furnace during light-off plus gas flow from ignitors. We must have an ignitor capable of doing a specific job or else reliably aborting main burner start. But first, and most importantly, we must have a burner that will light every time under certain conditions, and *we must know* those conditions, fully and surely.

How is this essential information to be obtained? It can only come from the burner manufacturer. We are imposing a formidable task upon him for he must determine and deliver complete basic data on his equipment as he expects it to perform *in the proposed furnace arrangement.* To bid a given job, the manufacturer might need to prepare three or four different sets of operating limitations. The reasonable engineer must expect that he will have to pay a part of the cost of finding and delivering this fundamental safety information. Time saved, elimination of guesswork and the ability to do the best total job will more than offset the added cost of this information.

Let us turn now to the component we rate second in importance in a safety system, the ignitor or pilot burner. We know that many operators use hand torches to light off. We admit that many prefer them! But if we are going to discuss the safest systems we know how to build, or systems that are automated, we must reject the hand torch. Here then is how we might set about specifying the functioning of ignitors:

SECTION II. IGNITORS. Each ignitor shall be a proven item of equipment capable of safely and reliably burning (type) gas, or (type) oil in the quantities specified under Section I, Burners, under the following conditions:

1. Air flow. The ignitor shall have the demonstrated ability to reliably light under these conditions as limited in Section I.

a. Maximum main burner air flow.

b. Minimum main burner air flow.

c. No main burner air flow.

2. Fuel flow (ignitor). The ignitor shall have the demonstrated ability to reliably light under these conditions as limited in Section I.

a. Maximum fuel pressure.

b. Minimum fuel pressure.

c. Where a separately controlled or regulated source of ignitor fuel is used, the ignitor manufacturer shall specify minimum and maximum fuel pressures for reliable light-off.

3. Proving device. Each ignitor shall be equipped with an integral proving device, which shall prove that the ignitor is releasing an adequate supply of ignition energy in the quantity and the area defined in Section I, so as to insure lighting the main fuel under any possible design condition. Said proving device shall self-check the ignitor against:

a. Improper ignitor air flow.

b. Improper ignitor fuel flow.

c. Ignitor spark failure.

4. Time of ignitor proving. Ignitor proving device shall indicate adequate ignition energy within — seconds, after ignitor is energized. Proving device shall remain in service during the entire time ignitor is in service to prove that energy release remains adequate.

We believe that Section II adequately specifies the second most important link in the chain of furnace safety, the ignitor. It is apparent, from comparing the length of Section II against the much longer Section I, that the task of specifying components becomes simpler as the work progresses. The function of the ignitor, for instance, could not be specified before we set the limits of burner performance. Having set those limits, we found that they automatically defined much of the ignitor specification. In addition, we automatically arrived at most of the required interlocks and their setting ranges. Perusal of these sample specifications will show where a number of requirements of the combustion control system are likewise spelled out.

This brings us back to our starting point, the role of the flame sensor. Rather than starting with a haphazard choice of a flame detector with hopelessly undefined functions, we have now built a fairly sturdy fence around what shall be required of the flame safeguard. By removing from consideration the jobs assigned to burner and ignitor, by setting up limits to be governed by interlocks and maintained by controls, we find that the responsibility of the flame detector is rather simple.

There are some, in fact, who may argue that given the burner and ignitor specified here, plus interlocks to protect burner and furnace services, there is really no need for a flame safeguard. We are not prepared to go that far.

Flame sensors are required for two simple but important reasons—to guard against failures of equipment and to guard against contingencies not anticipated by the system designer. Man has yet to build a device that can't fail and there are many, many ways of causing furnace explosions, but only one way to operate safely.

The flame sensor specification can thus be written rather simply. It should sense flame and only flame, and flame quality if possible. It should be unaffected by dirt, oil film, coal stream obscurity (density) and ambient temperature. Susceptibility to any of these latter should be covered by specific limits. Whether the sensor must sense in a restricted area will depend on *total system requirements* (what to do on a failure signal). Space requires that we leave this area to a study of the bibliography which presents a number of competent opinions.

Total system studies involve the philosophy of safety, and we feel it is vital to learn safety's basic language before aspiring to the higher arts. It is in this belief, and in the sincere hope that it will prove helpful, that this very basic approach to the specification is presented. The author was gratified indeed at the support of this position shown by E. S. Monroe in a recent article (Ref. 5), stipulating that a fundamental program for accumulating basic data on the combustion process is essential to greater safety of operation. END

References

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