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SOME ASPECTS OF THE GENERATION AND SUPPRESSION OF NOISE FROM COMBUSTION EQUIPMENT

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Introduction

As the trend towards more comfort goes on, it is natural to expect that an increased amount of attention will be directed towards the quietness of our environment. An essential comfort is warmth and its generation with the least amount of noise is therefore important.

Noise from Combustion Equipment

A combustion system has, in addition to the burner combustion space and stack, ancillary equipment such as motors, fans, controls, etc. The reduction of noise from much of the ancillary equipment is the concern of other papers so that it will only be referred to insofar as it influence adversely the process of combustion.

A useful exercise in any investigation of a noisy combustion installation is to carry out an acoustic analysis of the noise produced as the equipment is taken through its start up procedure. Fig. 1 shows the breakdown of noise from a rotary cup burner (1) (32,000 lb steam/hr).

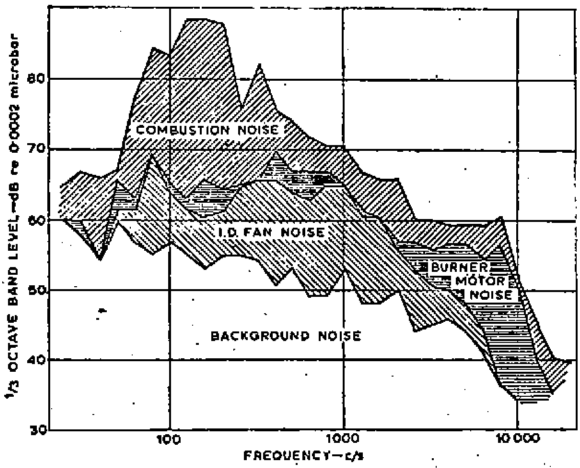

Fig. 1. Rotary Cup Burner Noise

A large proportion of the noise is seen to be due to combustion. A comparison with other burners of similar rating is given on Fig. 2 (1)

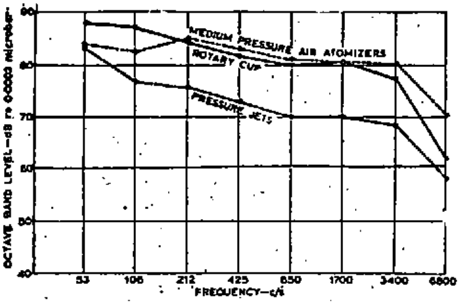

Fig. 2. Average Industrial Burner Noise

The pressure jet burner - for the particular samples examined - is seen to generate some 10 dB less noise than the rotary cup burner. Clearly, therefore, the manner in which fuel and air are introduced into a chamber will influence the type and amount of noise obtained from the flame.

Flame Generated Noise

In any study of the noise produced by combustion equipment, it is important to distinguish between the noise due to the process of combustion and that due to some interaction between the process of heat release and the acoustics of the environment. The latter may be the space in which the boiler is located and/or the space in which the flame is enclosed. Thus problems of resonance in inadequately vented boiler housings and problems of pulsations in boilers are not unfamiliar. Before proceeding much further it is therefore essential to describe the generation of noise from a simple open flame.

There are basic differences between the generation of noise from a flame - a reacting gas jet - and from a jet of gas. In a flame the seat of noise generation is to a large extent located in the reaction zone of the flame[2] [3]. Careful measurements have shown that the emission of noise from the flame can be related to and varies in sympathy with changes in the reaction rate of the flame. Also, unlike the gas jet, the radiation pattern of the noise from an open flame is similar to that of a monopole source of sound rather than a quadrupole source[4]. As a result, a flame is a much more efficient source of sound than is an unignited jet. It may thus be concluded that any process which modulates the rate of reaction of a flame by varying the fuel/air mixture will contribute to the noise generated.

Flame Systems Interactions

Modulation of the fuel/air mixture could arise from:-

1. An instability in the air supply system.

and/or 2. An unsteady fuel supply system.

3. A flame/acoustic interaction.

4. A flow/acoustic interaction.

Modulation of the air supply system could be due to unsteadiness in the supply of air from the available fan/duct arrangement. Alternatively, unsteadiness in the regulation of the fuel supply can be a source of trouble. Thus, fluctuations in the supply of fuel can lead to variations in combustion rate and hence chamber pressure which can adversely affect the intake of air[5].

In addition to the above mechanically induced pulsing, an acoustic coupling can occur between the rate of heat release and the generation and dissipation of pressure. This phenomenon is subject to Rayleigh's criterion which has been defined as[6]:

$$\oint h.\Delta p.dt > k$$

Thus if over a cycle of operation heat release (h) occurs when the pressure (Δp) is rising to an extent sufficient to overcome the damping then an acoustic oscillation will be sustained by the combustion process. In a similar way, where the natural eddy shedding frequencies of the flowing gases can lead to sufficiently strong variations in the rate of combustion at frequencies compatible with those of the enclosure, a resonance can be sustained[7]. Techniques for decoupling a resonating system vary[5]; thus venting the pressure rise, reflecting it back as an antiphase signal or redistributing the heat release from a flame may be employed. A typical case history is outlined below.

In an attempt to discover the cause of pulsation in a gas fired 3-pass 5 × 10^6 kcal/h boiler supplying an office block, tape recordings of the noise were made at the positions described on the table below and were subsequently analysed on a narrow band analyser. The analyses were interpreted thus[5]:

Position	Band frequency Hz 45-55	65-75	130-155
Air Intake (no combustion)	-	100 dB	104 dB
(with ")	106 dB	peak masked	130 dB (level increased due to combustion)
Front end of boiler (3 mm distance) with combustion	87 dB	peak masked	112 dB
Inside smoke box at rear of boiler	120 dB	peak masked	120 dB
Other locations	most audible near chimney		most audible in boiler house

These results suggest that the combustion chamber created most noise in the range 130-155 Hz and that even in the absence of combustion the pulsation was present at the air intake so that it is reasonable to suggest that the damping between the air intake and the combustion chamber should be increased, e.g. by extending the duct length and by the use of baffles. It is also noted that the chimney resonance is at a different frequency from that of the combustor - this is to be expected since the 3-pass arrangement could isolate acoustically the chimney from the combustor. The above observations suggest that if the resonance in the combustor were eliminated that of the chimney may still persist. One particularly bad instance of a resonating chimney was connected with the design of a block of flats. To avoid the unpleasant appearance of a single stack rising from the boiler house a brick chimney was built as an integral part of the building. As a result all the flats in the block became uninhabitable when the chimney went into resonance.

It seems appropriate that some mention should also be made of noise from domestic heating boilers. A comparison of the noise from a variety of heating units is shown in Fig. 3. The noisiest is seen to be the pressure jet burner[1] - whilst natural draught equipment is seen to be the quietest. With domestic burners a sensible proportion of the noise can be from the associated mechanical equipment. Suitable use of sound absorbing material and the enclosing of burner pump and fan air entry can lead to noise reductions of as much as 10 dB [1]. As with the larger boilers referred to earlier on, a boiler installed in the home can also pulsate. However, unlike the 3-pass boiler, when a domestic boiler goes into resonance both the combustion space and the chimney go into resonance together [8]. The simplest acoustic resonator typical of the domestic boiler is the Hemholtz resonator, which can be single or double necked. Predicting the resonant characteristics of a domestic boiler is complex and not yet possible.

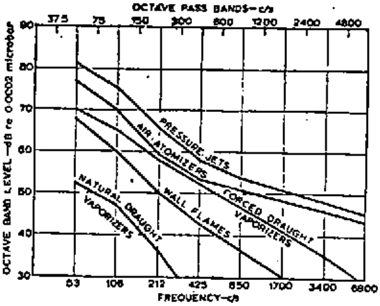

Fig. 3. A Comparison of Noise from Domestic Burner Installations

Having descended from the 3-pass boiler to the once-through domestic central heating unit some mention of the noise from room heaters is appropriate. The traditional town gas fired room heater is virtually silent. However, for satisfactory operation with natural gas the design of the burner has to be modified to allow some air to mix with the gas prior to combustion. Mixing of the gas with air is achieved by allowing the gas to emerge from a nozzle and pass into a venturi so that a controlled amount of air is also aspirated. If adequate shielding is not provided, the noise from the emerging transitional/turbulent jet can be a source of irritation. Besides shielding, the noise can be reduced by reducing the exit velocity of the gas but maintaining the throughput by utilizing multihole jets. In addition special aero-acoustic effects such as the use of high frequency inaudible acoustic fields to make jets quieter [9] could be adopted.

In addition to the work being carried out in different laboratories on noise from combustion equipment, organizations such as the Gas Council [10] and Dobeta (Domestic Oil Burning Equipment Testing Association) are involved in the setting up of acceptance standards for commercially available equipment. Noise from combustion equipment can clearly be kept to a minimum if sufficient care at the design and development stage is given to those aspects which could influence the generation of noise.

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