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OIL COMBUSTION NOISE

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The burner head used was a Shell combustion head, Fig. (1), which was chosen because of its flexibility i.e. able to support a stable open flame under a wide range of input conditions. Oil was supplied to the burner from a pressurized container and the excess air from a centrifrugal blower. A block diagram of the system is shown in Fig. (2). The oil pressure, and hence flow rate, was controlled by two reduction valves, 'A' and 'B' in Fig. (2), and the excess air flow by the 'Y' junction. The nozzles used were of the swirl type with quoted flow rates of 0.50 to 1.25 US gallons/hour at 100 p.s.

The work undertaken was divided into two sections. The first part dealt with the noise generated by the flame as a whole, while the second was a more fundamental approach to the problem by investigating the noise producing sources within the flame.

When dealing with the overall sound pressure level the variables considered were: (1) Excess air pressure: (2) Oil pressure/oil flow rate: (3) Nozzle characteristics. Of these three variables it was found that the excess air pressure had the greatest effect on the sound pressure level. Fig. (3) shows the S.P.L. (dB re 2.10^{-5} N/m^2) plotted as a function of the total excess air pressure. The nozzle type used here was one which produced a solid spray pattern with an included angle of 80° at an operating pressure of 100 p.s.i. Fig. (3) exhibits the characteristic features of all such plots obtained. A decrease in the oil pressure resulted in a decrease in the separation of the curves due to the difference in the flow rates decreasing with decreasing oil pressure. The sensitivity of the flame noise to changes in flow rate decreased with increasing flow rate for a given nozzle, but the maximum levels attained appeared to be independent of the flow rate. This can be explained on the basis of constant flame size. At the lower excess air pressures the increase of the sound pressure level was more rapid at the lower oil pressures. This may be explained by the fact that at the higher oil pressures the relative velocity between the spray and the excess air flow would be smaller than that at the lower oil pressures. As a result of this the turbulence imparted to the spray would be smaller for the higher oil pressures. As the excess air flow was increased the turbulent motions would be more readily imparted to the slower moving fuel droplets and vaporized fuel than the faster ones injected by a higher oil pressure. As a result the rate of sound pressure increase would be greater for the lower oil pressures.

The relationship between the mass flow rate of fuel and the sound pressure level showed uncertain characteristics. However, two reliable trends did emerge. With Zero excess air pressure the relationship between the sound pressure level and the flow rate was linear for all nozzles and as the excess air pressure was increased the S.P.L. became less dependent on the flow rate. Indeed, for the lower capacity nozzles the S.P.L. was found to be independent of flow rate for excess air pressure of 0.70 and 0.50 ins w.g.

The shape of the frequency spectra was found to be independent of the operating conditions with the S.P.L. reaching a maximum in either the 125 or 63Hz octave band after which the level fell off at approximately 6dB/octave. This constant frequency characteristic was probably due to the distribution of droplet sizes not changing significantly as the oil pressure was increased.

Suggestions for Noise Reduction

Small but not practically useful noise reductions can be obtained by replacing a nozzle with a larger capacity one and operating the latter at a reduced oil pressure so as to maintain a constant mass flow rate. By this method only reductions of up to 3dB could be achieved. A now common technique for reducing the noise levels in gas fired appliances is to replace a single hole injector by one having 5 or 7 exit ports such that the volume flow of gas is not reduced. By this method S.P.L. reductions of up to 10dB can be achieved (1). Consider the case of a pressure jet oil burner. If more than one flame is to be used the total flow rate of the composite flame must equal that of the single flame in order to maintain a constant heat output. If two flames were maintained at the same excess air pressure as the equivalent single flame an increase in the S.P.L. would result. However, the reduced flow of fuel to the separate flames will be associated with a corresponding reduction in the excess air supply. In this way it was estimated that reductions of up to 3dB could be achieved, which again cannot be considered as being practically worthwhile. It must be pointed out at this stage that only a rough estimation of the efficiency could be made but it was found that the most efficient flame was the one which made the most noise. Because of this the overall conclusion has to be that no effective noise reductions could be achieved on the open flames examined by changes in the variables considered while still maintaining their stability and efficiency.

Noise Sources Within the Flame

The electrical resistance of the flame was controlled by the number of free electrons present which in turn would be determined by the amount of fuel being burnt. It was found that the flow rate of fuel, Q, to the flame was proportional to the electrical resistance of the flame. If the mechanism of noise production is assumed to be by monopole sources where the sound pressure, p(t), is proportional to the rate of change of mass evolution i.e. $p(t) \propto dQ/dt$, then the time differential of the resistance would yield a value proportional to the local sound pressure. This approach constituted the second part of the work.

To detect the ion producing, and hence combustion, centres of the flame a pair of electrodes was used. These were scanned in a horizontal plane bisecting the flame. A typical set of results is shown in Fig. (4) which gives the variation of $dI/dt \propto dQ/dt$ with position. Here the spray nozzle used was one producing a droplet distribution with a high concentration along the axis and the effect of this distribution on the regions of noise production is clearly shown. The distribution of noise sources throughout a flame may be significant in determining the acoustic coupling of an enclosed flame with its combustion chamber.

The sound field at a point near the flame is, however, produced by the total of the noise sources in the flame and a correlation analysis was made between the time differential of the ionisation current of the whole flame and the external noise. The most prominent octave band in the frequency analysis of the combustion noise was centred at 125Hz and Fig. (5) shows the cross-correlogram of p(t) and $^{dI}/dt$ for this pass band. The major peak is displaced 2ms from the origin as would be expected from the microphone position, and a periodic component with a period of about 8ms is shown. A similar cross-correlogram was obtained from the unfiltered signals and although the correlation was lower the common factor of 125Hz components was still apparent.

Reference (1) Roberts and Leventhall - Applied Acoustics 4, pg 103, 1971.

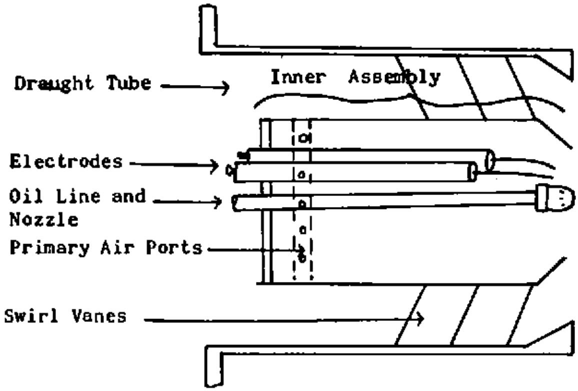
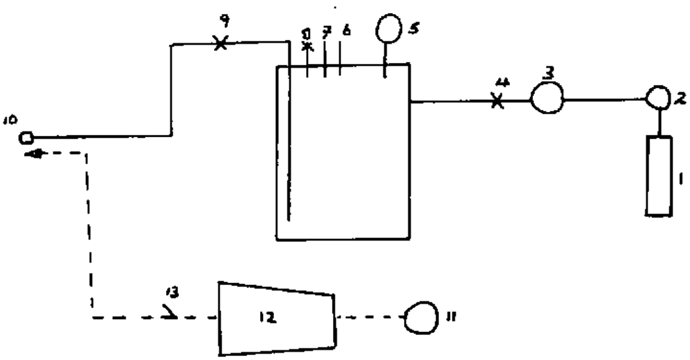
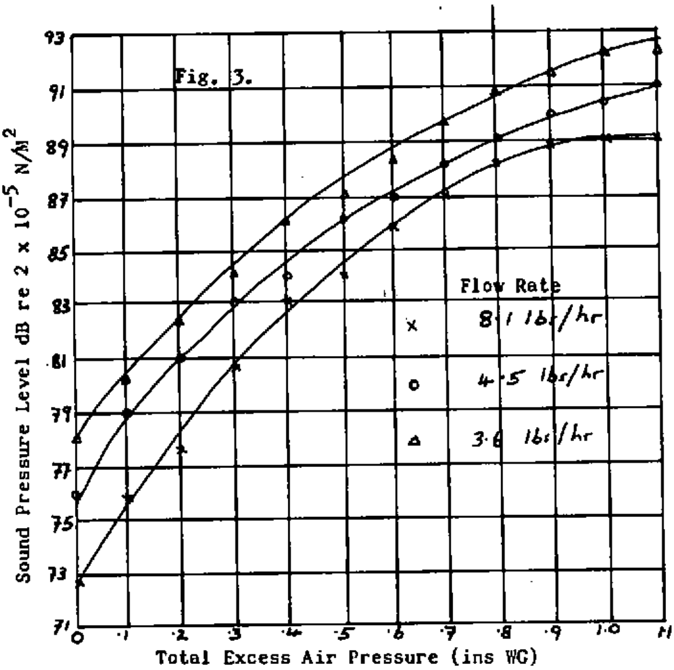


Fig. 1. THE SHELL COMBUSTION HEAD



1. High Pressure Nitrogen Cylinder. 2. Reduction Valve A.
3. Reduction Valve B. 4. Nitrogen Gate Valve. 5. Test Gauge.
6 & 7. Safety Valves. 8. Container Pressure Release.
9. Fuel Gate Valve. 10. Nozzle. 11. Blower. 13. Air Control Junction.

Fig. 2. THE COMBUSTION SYSTEM.



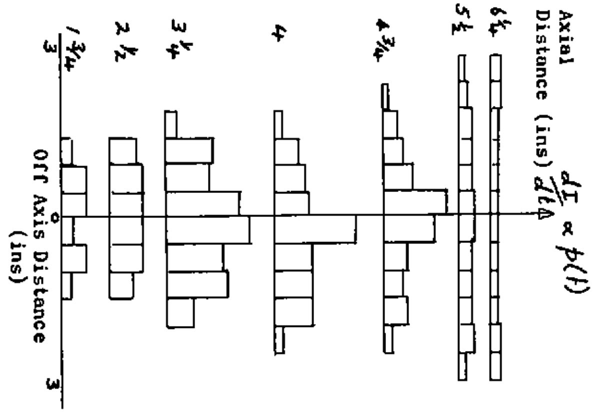


Fig. 4. Distribution of noise sources within the flame

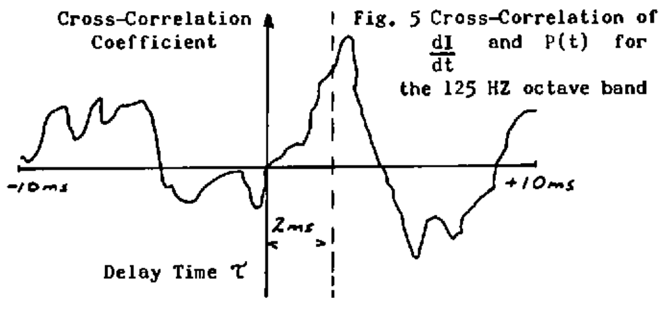


Fig. 5 Cross-Correlation of $\frac{dI}{dt}$ and P(t) for the 125 HZ octave band