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ACOUSTIC REDESIGN OF A HOT AIR BALLOON BURNER

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INTRODUCTION

The modern hot air balloon is fired by a propane fuelled burner which was developed in the early 1960's and since then has changed little in design. These burners are accepted as simple and efficient, and there is an element of trust from their users. The enthusiast for the sport tends to ignore the high noise levels generated. However, this burner noise can be a source of annoyance particularly to farmers due to animals panicking when balloons appear overhead and, in extreme cases, there have been reports of spontaneous abortions. The sport is becoming increasingly popular and noise generation could become a significant problem. This paper reports on investigation into the noise from such burners to determine whether some simple redesign could reduce noise output.

The Burner.

The gross weight of a balloon and additional equipment is dependent on its design but is typically over 3000 Kg. It is clear that a large amount of heat is required to produce the necessary thermal lift. Additionally, for safety reasons, the rate of heat input must be sufficient to ensure a rapid response of the balloon. The result is that most balloon burners are rated between 1.2 and 2.9 Mwatts.

Burners developed in the past two decades have changed little in basic design concept. Figure 1 shows a typical burner; comprising of vaporising coils, fuel jets, pilot burner and holes in the outer casing to allow inflow of air.

Liquid propane is forced by its own pressure to the vaporising coil of the burner. The coil serves as a heat exchanger using the heat of the flame to vaporise the liquid fuel. The fuel gas is expelled from the nozzles in the form of jets at a pressure of over $700 KN/m^2$, a speed of up to 260m/s and a temperature up to 100 degrees celsius.

The high velocity jets of gas mix with the surrounding air and are ignited by the pilot light which is fed by a separate low pressure fuel line.

A well designed burner improves combustion in three ways:

1) By vaporising the fuel before it mixes with air.
2) Multiple orifices mix the air and fuel in approximately the correct quantities before combustion begins, resulting in a more efficient and intense flame.
3) Producing a flame which is stable in shape and position.

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Burner Redesign.

Intense combustion requires high turbulence levels for efficient fuel gas air mixing. Such a requirement is in opposition to those for low sound output. A dilemma thus exists in burner design, for quietness the burner should have low flow velocity and turbulence levels, but for satisfactory combustion quite the opposite is required.

In measurements made on the standard burner combustion noise was shown to predominate over all other sources, and the essential approach to quietening this was based on the work of Strahle [1], Kilham et al [2] and Lighthill [3]. This body of work predicts that the sound output from the flame should be dependent on laminar flame speed, mean flow velocity, burner port diameter and mean flow density.

Theoretically then the redesign of the burner port could significantly reduce sound power output. Combining increased port area with use of the Coanda effect to entrain ambient air in a non-turbulent manner [4] produced the design shown in figure 2. Only one size of burner was constructed, this was of mild steel throughout with a fuel slot of 0.2mm angled at about 10^{o} upwards. The total port area was about twice that of the burner ports of the similar standard burner. The final flame was very similar to that from the standard burner and performed quite satisfactorily in tests.

Measurements and Results.

Measurements conformed to standards BS 4196:Part 4:1981 [5], ISO 3744-1981 (E) [6] and ISO 2204 [7]. Measurements were made in the far field over a reflecting plane. The test site was clear from any reflecting objects for a distance of over 50 metres in all directions from the source. The ground was flat, hard and covered with short grass. All measurements were made on hot, dry days with no cloud cover. Wind velocities varied from 0-4 knots, dry bulb temperatures ranged from 19^{o} to 26^{o} celsius and relative humidity from 70% to 95%.

Measurements of linear sound pressure level were recorded at eight positions in the hemisphere above the ground at a radius of 6.0m with the source as centre. The burners were held in their usual framework 1.0m above the ground and fired horizontally. Measurements were analysed in octave bands from 31.5 Hz to 31.5 KHz.

The two burners, standard and Coanda were regulated to produce a heat output of 2.9 Mwatts. Figure 3 shows a typical plot of octave band sound pressure levels, in this case at 0^{o} to the burner axis. Similar plots were obtained at 45^{o}, 90^{o}, 135^{o} and 180^{o}, these are shown in Table 1. Figure 4 shows the overall sound pressure level as a function of angle from the burner axis. Figure 5 shows sound power output as a function of frequency.

Conclusions.

The results show a decrease in the overall sound pressure level of between 4 and 6 dB depending upon directionality, and a decrease of sound power ranging from 4 to 15 dB depending upon frequency. These are significant reductions in sound output and appear to have been achieved without loss of combustion efficiency. It now remains for the burner to be tested operationally over a period of time to see how it performs in practice.

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[5] BS 4196:Part 4:1981, Engineering methods for determination of sound power levels for sources in free field conditions over a reflecting plane.

[6] ISO 3744-1981(E), Acoustic determination of sound power levels of noise sources- engineering methods for free field conditions over a reflecting plane.

[7] ISO 2204, Acoustics- Guide to international standards on measurement of airborne acoustical noise and evaluation of its effects on human beings.

TABLE 1. Octave Sound Pressure Level (dB) at Various Angles from the Burner Axis.

ANGLE FROM BURNER AXIS (DEG).	31.5	63	125	250	500	1K	2K	4K	8K	16K
COANDA BURNER.										
0	82	87	85	77	80	72	60	59	60	59
45	83	88	86	82	85	77	68	62	67	66
90	81	87	87	85	88	79	70	67	70	68
135	84	85	87	83	80	77	71	69	73	70
180	82	96	85	80	82	75	71	70	72	68
TYPICAL BURNER.										
0	84	91	88	85	85	82	74	74	77	69
45	85	92	88	86	87	83	76	75	82	76
90	87	94	92	88	92	85	80	84	88	83
135	86	92	91	87	88	85	77	80	84	75
180	88	91	88	86	82	78	73	74	75	73

Column heading: OCTAVE FREQUENCY (Hz).

The 31.5 KHz octave band was analysed but the sound pressure levels obtained were 50 dB or below.

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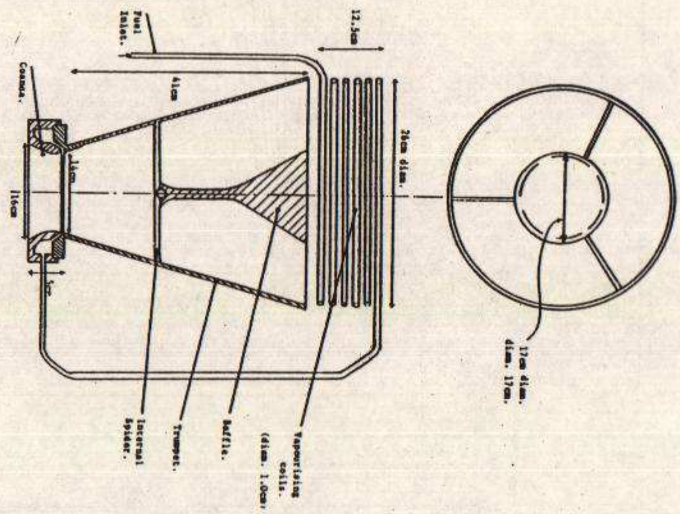


FIGURE 2
Coanda Burner.

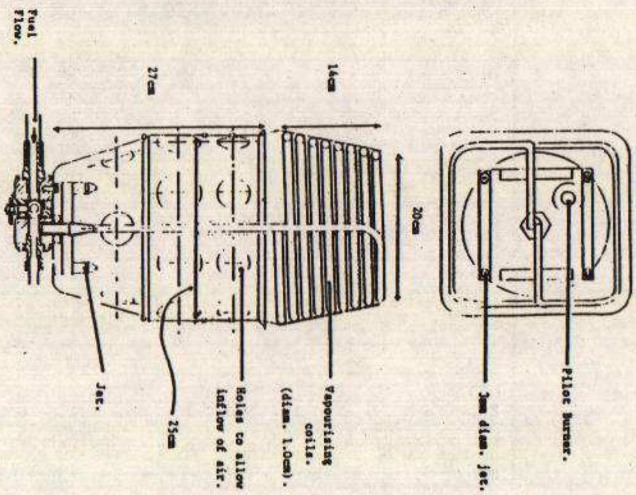
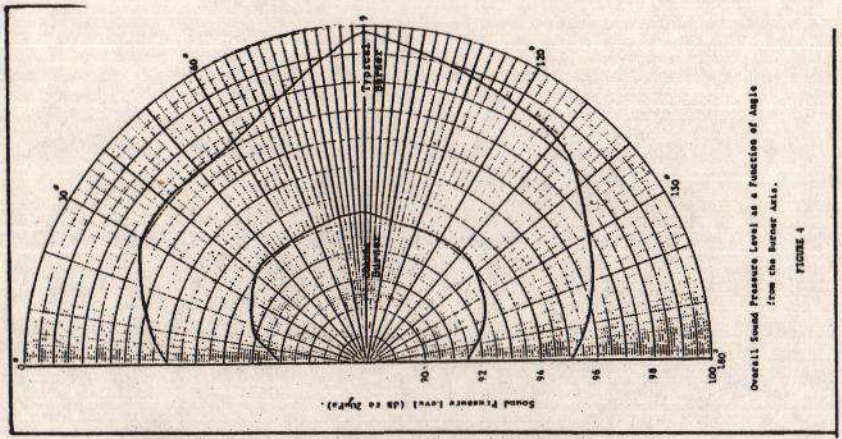


FIGURE 1
Typical Burner.



Overall Sound Pressure Level as a Function of Angle from the Burner Axis.

FIGURE 4

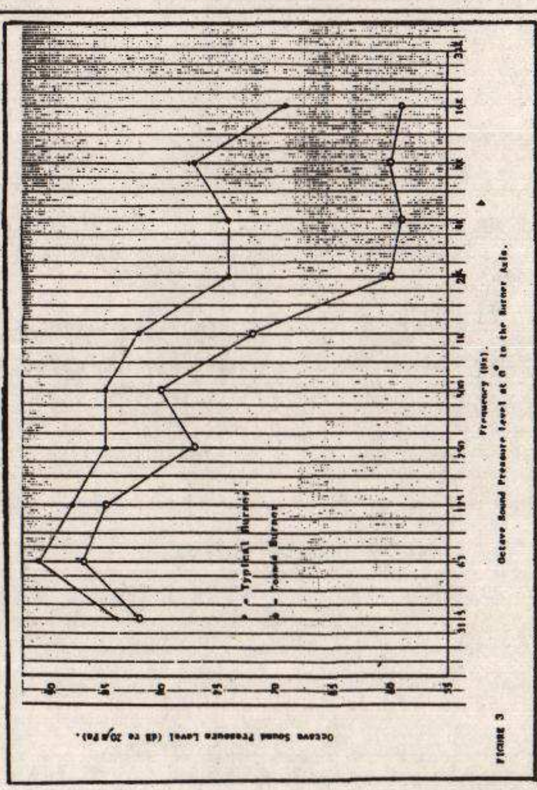


FIGURE 3

Octave Sound Pressure Level at 0° to the Burner Axis.

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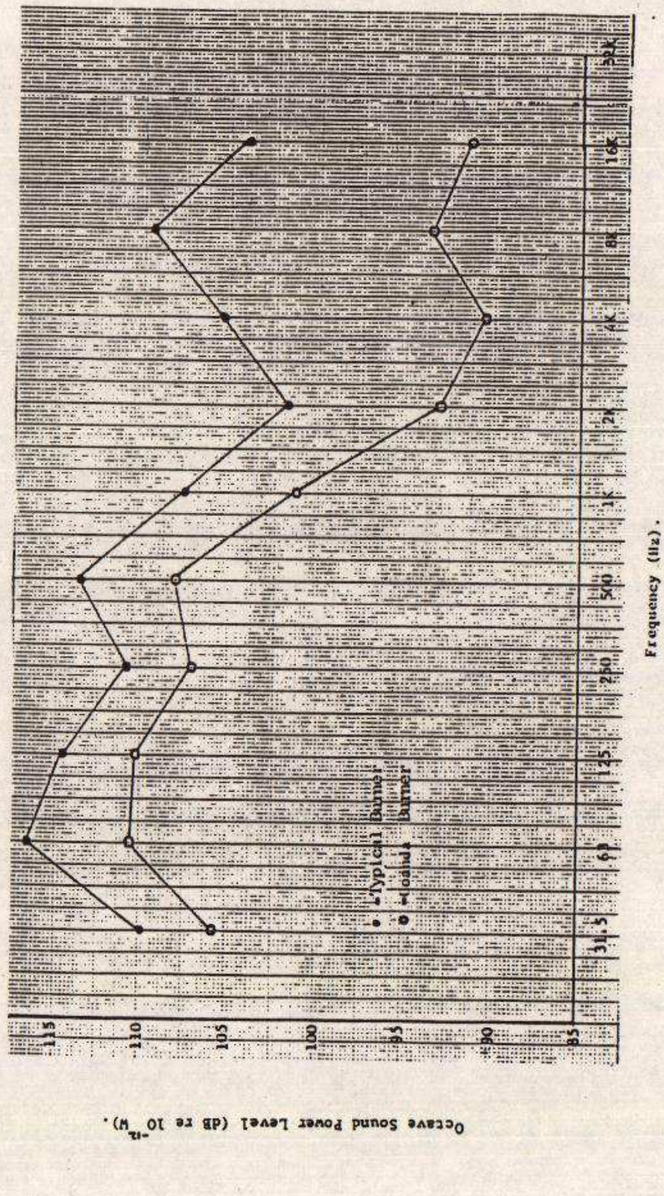

FIGURE 6 Octave Sound Power Level.