Taming the roar of a gas flame

A small flame quivers in response to the melodious sound of a gently bowed violin. An ear-splitting roar issues from a 1·5-MW industrial gas flame firing a reverberatory furnace.

In both cases, the phenomena have similar physics, but we lack a satisfactory explanation of what's going on.

Scientists at the CSIRO Division of Energy Technology have been seeking to understand how gas flames produce sound, so that they can work out ways to reduce the noise levels of industrial gas burners, particularly those in the aluminium industry.

Here, gas-fired burners with flames more than 2 m long and a heat output of 1·5 MW are used in reverberatory furnaces to melt aluminium ingots and scrap metal into alloys. Troublesome noise levels in excess of 100 decibels can occur when the flame is turned up fully. Although this level corresponds to only one ten-millionth of the flame's energy being converted to sound, it is well above the acceptable limit of 90 dB for continuous exposure of unprotected workers.

As a consequence, the flame has to be turned down whenever the furnace door is open,

An industrial reverberatory furnace.

which it is for appreciable periods during charging of the furnace. And so melting times, already many hours, are significantly prolonged.

The CSIRO study began after Alcoa of Australia sought help in overcoming a noise problem at its Pt Henry plant. The company wanted to make flames quieter so that operators could achieve acceptable noise levels without turning down the flame.

Alcoa is helping meet the cost of the study, which involves Dr Andre Cabelli as leader, and Mr Ian Pearson and Mr Ian Shepherd.

In addition to conventional sound-analysing equipment, the researchers are using a powerful pulsed laser to take short-exposure photographs of sections of a scale-model flame in their laboratory. They have also run experiments with a full-size industrial burner operating in the open air.

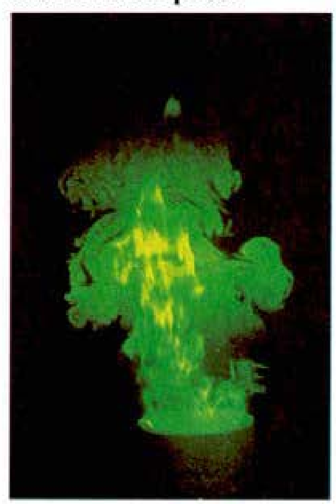
The gas-fired reverberatory furnaces at Pt Henry, typical of many units, use a nozzle that ejects air and gas from different holes. Mixing of the reactants and combustion take place simultaneously, unlike what happens in domestic gas appliances, where gas and air are mixed first before burning occurs. The former arrangement has two advantages: it's safer, and the flame is easier to control. Coincidentally, it's also less noisy.

The difficulty with investigating combustion processes is that many factors are operating at once, and it's not easy to establish the conditions that give the quietest combustion noise while keeping all the other flame properties — length, colour, uniformity, stability, and so on — at their optimum.

To study the effect of various nozzle arrangements and conditions, the researchers built a scale-model burner with a capacity of 30 kW. Interchangeable components allowed various configurations to be tried, and measurements of the various factors at work were taken and stored by microcomputer-controlled instruments.

Experiments showed that the nozzle geometry and the relative velocities of the air and gas jets had a considerable influence on the noise output of the burner. The team found

A flame frozen by the intense flash of a laser pulse.



Scientists used a scale-model burner to find ways of reducing the noise of much larger industrial units.

that imparting swirl to the incoming air improved the stability of the flame, allowing them to make changes in the nozzle geometry that gave an immediate reduction of 5–10 dB(A) in noise level.

Aerodynamics turned out to play a major role in the flame's behaviour. In order to understand how the processes at work produce noise, the team needed to picture these and then relate them to the noise generated. They used a powerful neodymium-YAG laser, with a 20-ns pulse providing a peak output of 1 MW, to illuminate the flame with a sheet of intense green light. When they seeded the airstream with fine inert powder, the flow and mixing patterns within the flame were 'frozen' by the brief light flash and became dramatically visible, as shown in the picture.

The researchers are now looking at the sound-generating mechanism more closely. They are superimposing tones of definite frequency on the flame, and using the laser to see how each one modifies the flow and noise output.

The study is still proceeding, and the scientists can't yet say what causes noise to issue from flames. However, they have found that, since the processes involved are so complex, scale models do not always give the right answer. They therefore turned to full-scale tests, done outdoors, to verify the most promising model results.

Gratifyingly, when they applied modifications suggested by the model to the full-size flame, they found that noise reductions were significantly larger than the model indicated. Having achieved noise reductions of up to 12 dB(A), they believe that the production burners will be at least that much quieter too.

In addition, the pressure of air feeding the burner has been reduced by about 90%, leading to a substantial saving in the power needed to drive the pressurising fan (and a reduction in fan noise as well).

Soon, modifications suggested by their research will be made to a number of production burners. Dr Cabelli believes that these units will then have sound levels below 90 dB(A) even at maximum firing rates.

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Turbulent diffusion gas flame noise. A. Cabelli, I.G. Pearson, and I.C. Shepherd. *Proceedings, Australian Institute of Energy National Conference, Melbourne, 1985.*