

Vibration	Combustion Oscillation in Ground Flare	Plant
Combustion Oscillation		

Object Machine

Ground flare (off-gas combustion treatment facility)

Observed Phenomena

A ground flare shown in Fig.1 has four-fold ring type burners. As the amount of treating gas increases and the pressure in pipe rises, treating gas is provided to the outer periphery burners in succession. When switching the combustion mode of the three burners (first to third stage) to the four burners (first to fourth stage), combustion oscillations of such a large magnitude occurred that the windows of private houses several km apart were shaken.

Cause Estimation

This phenomenon is considered thermo-acoustic combustion oscillations ^(1,2) that were generated where variations in calorific power and pressure are coupled.

1. A heat source (flare) was present at the bottom of the both-end open pipe (ground flare stack installed vertically).

2. As the flare varied with time (visually observed).

By above two states, it was assumed to be combustion oscillation to occur by the mechanism similar to that of Rijke pipe. As flare was short at the time of starting to use the fourth burner, and was in the most spread condition (Fig.2), coupling is likely to happen between the sound waves (pressure variations) propagating in the ground flare and variations in calorific power. It is thus assumed that only in this operation mode, the combustion oscillation occurred.

Analysis and Data Processing

After installing a microphone and thermocouple to measure the combustion gas temperature, the oscillation frequency and the combustion gas temperature were determined. The acoustic natural frequency of the ground flare (8 to 10Hz, both-end open pipe) calculated by using the temperature data and the ground flare size agreed with the measured oscillation frequency (Fig.3, 8.1Hz). Variations in the upstream side pressure gauge confirmed temporal variations in the flowrate of treatment gas, which is found to cause variations in calorific power. Thus, it was judged that a cycle (thermo-acoustic oscillation) was formed: pressure variations -> variations in the amount of treatment gas -> variations in calorific power -> pressure variations.

Countermeasures and Results

Since elongation of flare can reduce variations in calorific power⁽³⁾, a countermeasure was taken to elongate the flame at the time of starting the fourth stage burner. Specifically, the opening/closing time of the fourth stage burner control valve was adjusted, so as to allow treatment gas to spout from the nozzle at a high speed. By increasing the jet flow speed, flame spreads in the direction of main flow (Fig.4). The result of this countermeasure succeeded in reducing the peak pressure by 20dB (Fig.5).

Lesson

Thermo-acoustic oscillations occur due to temporal variations in calorific power. It is thus necessary to design a fuel and oxidant supply system that is strong against external disturbances. For instance, it is effective to install a buffer tank on the supply system or to provide a mechanism to prevent pressure variations from propagating to the supply system. As in this case, it is also important to design so that flare does not become short.

References

- (1) A. A. Putnam, Combustion Driven oscillations in Industry, Elsevier (1971)
- (2) Dowling, A. P., 6th International Congress on Sound and Vibration (1999) pp.3277-3292
- (3) S. Kato et al, Proceedings of the Combustion Institute 30 (2005), pp.1799-1806

Keywords

Combustion oscillation, noise, thermo-acoustic oscillation, ground flare, air-column resonance

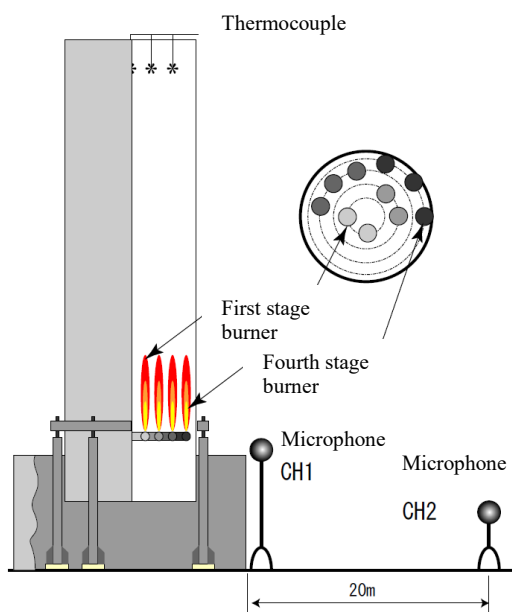


Fig.1 Outline of ground flare

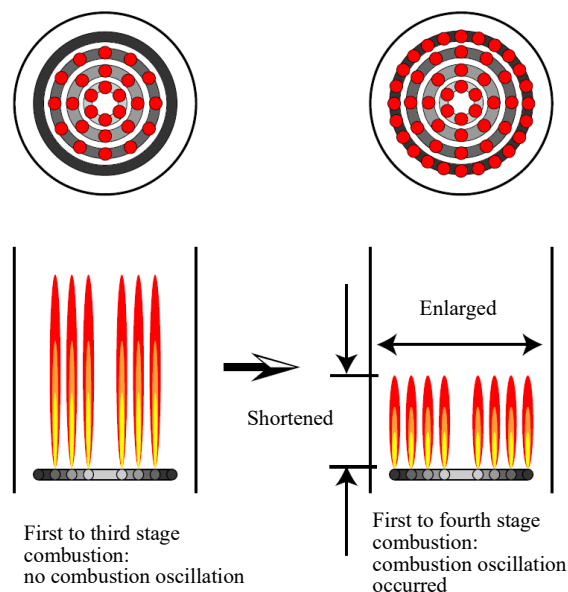


Fig.2 Schematic diagram of flare upon occurrence of combustion oscillation

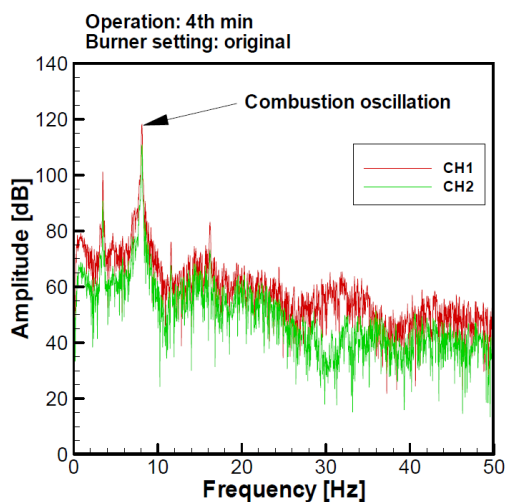


Fig.3 Result of FFT analysis during combustion oscillation

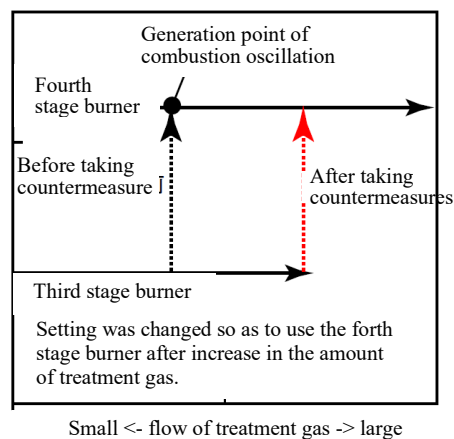


Fig.4 Contents of countermeasures

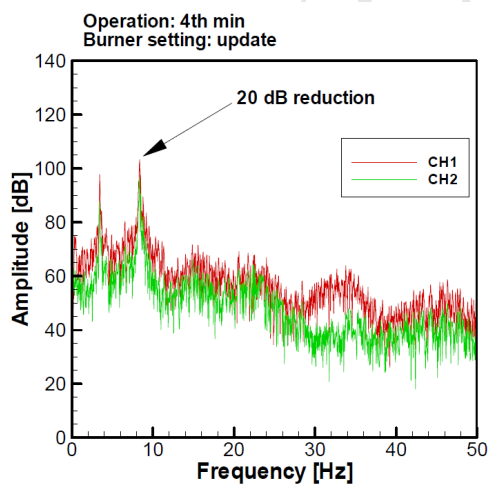


Fig.5 Result of FFT analysis after taking countermeasures against combustion oscillation