# HEAT REMOVED BY THE BURNER AS A MEASUREMENT OF DEGREE OF EXTINGUISHMENT

Chris Spencer, G. Dana Brabson, Edward A. Walters and Justin Schiro
Chemistry Depattment
University of New Mexico
Albuquerque, NM 87131
Phone: (505) 272-9837, Fax: (505) 277-2609

and

Robert E. Tapscott and Roger A. Patterson
New Mexico Engineering Research Institute
Center for Global Environmental Technologies
901 University Boulevard SE
Albuquerque, NM 87106-4339
Phone: (505) 272-7252, Fax: (505) 272-7203

## INTRODUCTION

Recalling that Botha and Spalding found a nearly linear relationship between observed flame speed and the amount of heat removed by the burner,' it was decided to explore heat removal as a measure of the approach to extinguishment. The preliminary results of this investigation suggested that the amount of heat removed by the burner is a satisfactory indicator of degree of extinguishment.' The results presented here confirm the earlier findings, and illustrate that this type of experiment sheds light on the chemical processes operative in the flame.

## EXPERIMENTAL

Figure 1 illustrates the key components of the experiment. The Sapphire 0-4 Burner is a modified laboratory Meker burner (diameter = 3.7 cm). The heat absorbed by the burner is carried off by ethylene glycol, circulated at a measured flow rate by a gear pump through a cooling loop (3/16" copper tubing) silver soldered to the outside of the burner rim. The increase in the temperature of the ethylene glycol is measured by a pair of thermocouples located in the cooling loop just below the points of attachment of the loop to the burner rim. In typical experiments, 200-500 calories/minute were removed from the burner by the coolant. The

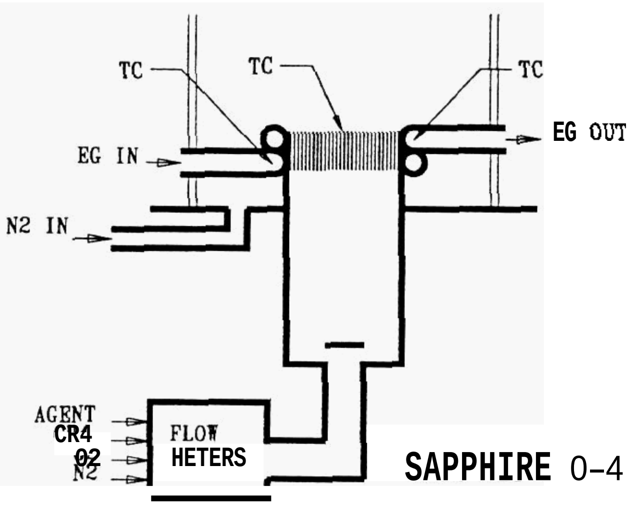
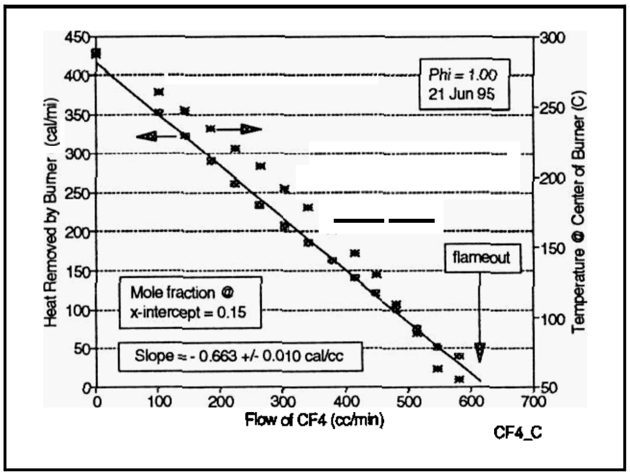


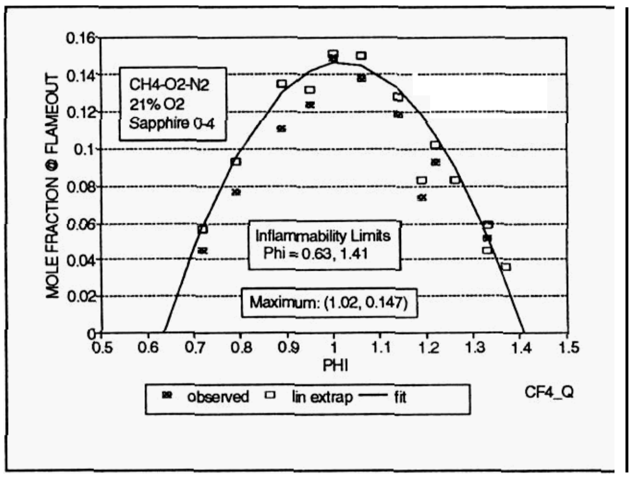

Figure 1. Features of the Sapphire 0-4 Burner

inflammability limit.

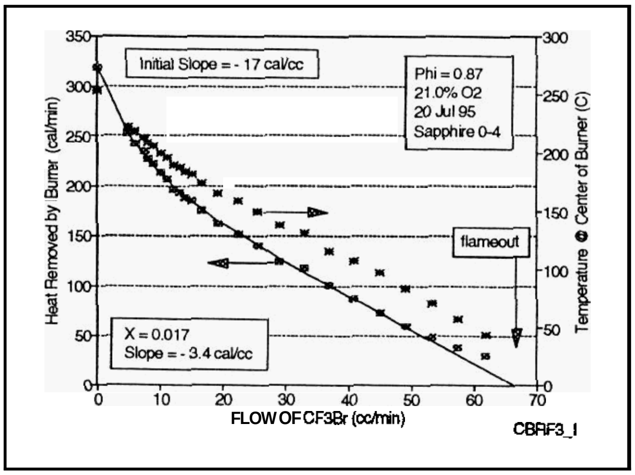
## RESULTS

*$CF_4$.* Extinguishment by $CF_4$, a typical physical extinguishing agent, was examined over a wide range of fuel-lean to fuel-rich flames. The results for a Type 1 experiment with a stoichiometric flame are displayed in Figure 2. The observed linear decrease in heat extracted by the burner as a function of $CF_4$ flow rate is typical of all experiments with $CF_4$; similar results have been



$CF_3$ is illustrated by Figure **4.** The first step in this experiment is characterization of the uninhibited flame from the lean inflammability limit to the rich inflammability limit. **A** fixed flow rate of extinguishing agent is then introduced and the experiment is repeated. The difference between the values recorded for the uninhibited and inhibited flames is a measure of the effectiveness of the extinguishing agent. The Fractional Extinguishment Efficiency (FEE) is then defined as the ratio of this difference (in




this experiment (and in other experiments, both with Halon-1301, and with other catalytic chemical extinguishants) are best fit with an exponential equation of the form $y = a + b\,e^{-cx}$. The initial slope of the curve (from the exponential fit), unequivocally demonstrates that the decrease in heat extracted by the burner can not be attributed to a simple absorption of heat due to the heat capacity of the Halon-1301. The curvature of the data in Figure 5 is directly attributable to the

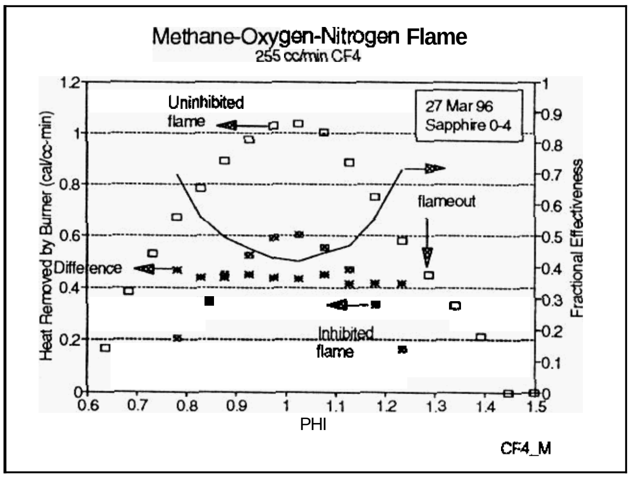


Figure 6 is remarkably similar to Figure 3, which presents equivalent data for CF,

Figure 7 summarizes the results for five Type 2 experiments with Halon-1301. It is evident from these data that Halon-1301 is more effective in reducing the amount of heat absorbed by the burner in fuel-rich flames than in fuel-lean flames. This is consistent with published reports that the effectiveness of Halon-1301 when introduced into the fuel side of a diffusion flame is different from the effectiveness of Halon-1301 when introduced into the oxidizer side of the same flame.

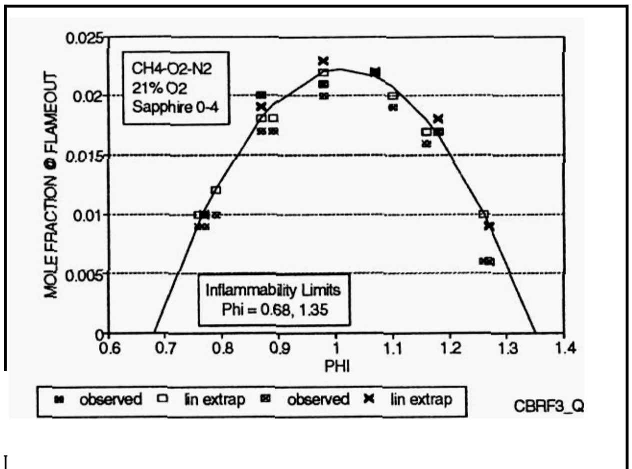



**Figure 6.** Extinguishment by Halon-1301

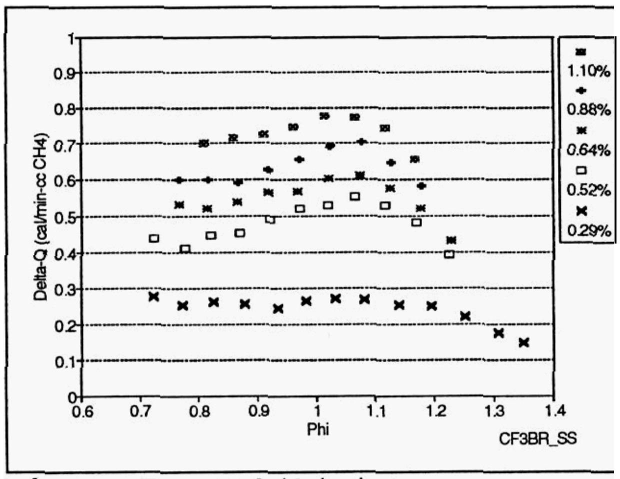



**Figure 7.** Inhibition as a Function of Volume Percent Halon-1301

*Other* ***agents.*** Comparative data for several agents are collected in Table 1. For comparison with the Cup Burner data, the volume percent at extinguishment reported here is the value at the peak of the Heat Removal curve. For N, CF, and $CF_3Br$, this peak corresponds to a stoichiometric flame. For $HCF_3$ and $HC_2F_5$, this peak corresponds to a fuel-lean flame, because the extinguishing agent contributes fuel to oxygen-rich flames. It is noted that the value reported here for Halon-1301 is lower than the Cup Burner values; it is speculated that this difference may be related to the fact that, in the experiments reported here, the agent is premixed with the fuel-oxidizer stream. In the Cup Burner experiments, on the other hand, the relatively heavy Halon-1301 molecule must diffuse and be entrained into the flame, and this could render it somewhat less effective in Cup Burner experiments compared with Sapphire experiments.

## CONCLUSIONS

When one compares the Cup Burner data with the results reported here for the most difficult flames to extinguish (viz, at the peak of the Heat Removal curve), the results are in remarkable agreement; this agreement validates both experiments. In addition, experiments with the Sapphire burner provide significant insights into the flame extinguishment chemistry.

| Extinguishing Agent | Dominant Extinguishing Mechanism | $\phi$ @ Peak of Curve | Volume Percent @ Flameout | |
|---|---|---|---|---|
| | | | This Work | Cup Burner[3] |
| $N_2$ | Physical | 1.01 | 31 | 30 - 31 |
| $CF_4$ | Physical | 1.02 | 14.7 | 13.8 - 16.0 |
| HCF, | Physical | 0.72 | 12.0 | 12.0 - 12.7 |
| $HC_2F_5$ | Physical | 0.65 | 7.9 | 8.1 - 9.4 |
| $CF_3Br$ | Catalytic Chemical | 1.01 | 2.2 | 2.9 - 4.0 |


1. J. P. Botha and D. B. Spalding, Proc. *Roy. Soc.*, *1954*, 225, 71. "The laminar flame speed of propane/air mixtures with extraction from the flame."

2. G. D. Brabson, R. A. Peterson, E. A. Walters and R. E. Tapscott, "Characterization of Extinguishants by Heat Extraction from Flames," Halon Options Technical Working Conference Proceedings, 9 - 11 May 1995, Albuquerque, NM.

3. "Cup Burner Values for Halons and Halon Replacement Candidates," Technical Update Series CGET1, Center for Global Environmental Technologies, New Mexico engineering Research Institute, The University of New Mexico, Albuquerque, NM. 7 May 1995.