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The Design and Performance of a Long-path "Multi-flame" Burner for Atomic Absorption Spectrophotometry

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In atomic absorption spectrophotometry, different kinds of burners must be used depending on the nature of the flames employed. For example, a 10-cm slot burner is used for an air-acetylene flame, a 5-cm slot burner for a nitrous oxide-acetylene flame, and a nebulizer-burner of the total-consumption type for air-hydrogen and inert gas-hydrogen flames. Several elements require a specific flame; for example, refractory elements require a nitrous oxide-acetylene flame, and some others prefer low-temperature inert gas-hydrogen flames. Therefore, at least the three kinds of burner mentioned above must be provided when a good number of elements are to be determined under the best conditions.

In this experiment, a long-path slot burner of a new type, one which permits various flames to burn, was designed and constructed. Its performance and use in atomic absorption spectrophotometry will be described below. The authors call this new burner a "multi-flame" burner.

Design and Construction

The production of a stationary flame requires that the stream velocity of the fuel-oxidant mixture through the burner slot is at least equal to the burning velocity. If this condition is not met, the flame is liable to flash back down the burner and cause an explosion in the nebulizer chamber. The problems of designing burners for relatively high-temperature flames particularly arise principally from the fact that gas mixtures with high flame temperatures usually have high burning velocities. This requires a limitation of the size of burner slot, with the attendant disadvantage of easier blockage by deposits of salt or carbon particles. It may be noted also that, for some gas mixtures, the burning velocity increases with the temperature of preheating,[1] so the burner head should be kept sufficiently cool; it must

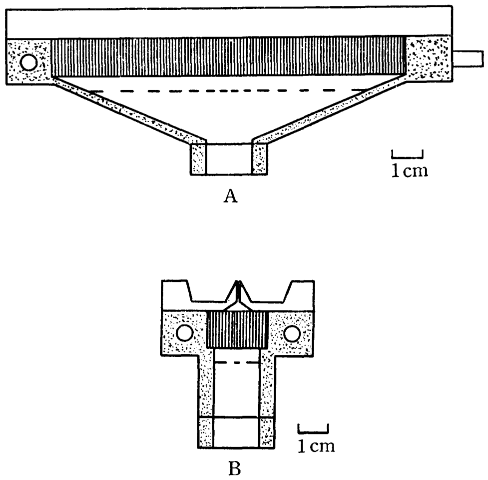

Fig. 1. Diagram of a "multi-flame" burner designed and constructed for atomic absorption spectrophotometry.
A: front view, B: side view. ▥ porous ceramic plate, ▩ brass casting, ▭ brass, ---- baffle, ○ duct for water-cooling.

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[1] A. G. Gaydon and H. G. Wolhard, "Flames, Their Structure, Radiation and Temperature," Chapman and Hall, London (1960), p. 80.

in any case be kept well below the ignition temperature of the gas mixture.

In view of these requirements, a new-type burner head which can be adapted to any premixed-type burner was designed. The burner head is shown schematically in Fig. 1. It consists of a burner top and a top holder, both of which are made of brass because of its facility of construction, though stainless steel would be preferred. The burner top consists of two pieces of surface-ground plate of the same features; these pieces form a slot and grooves. The slot serves as a nozzle. An outlet area of the nozzle is 1/23 that of the inlet. The length and width of the slot are 11.5 and 0.045 cm respectively. The height of the nozzle is 1.0 cm. To ensure an adequate entrainment of secondary air, the outer surfaces of the nozzle are tapered toward the groove, which is 1.7 cm wide and 0.7 cm deep. The rapid build-up of carbon particles and salt deposition, and the production of water when hydrogen is used as a fuel, were thereby minimized. To maintain the stability of hydrogen flames, which are liable to flash back down the burner and cause an explosion in the nebulizer chamber because of their higher burning velocity, a porous ceramic plate which contains about 50 holes (0.5 mm in diameter) per cm^2 and which is 1.25 cm thick, commonly used for a gas-infrared stove, is placed inside the top holder. Two ducts are provided in the top holder for cooling the burner top with water. The purpose of these ducts is to increase the effectiveness of the quenching action at the burner slot.[2]

Experimental

In this study the "multi-flame" burner was fitted to a Techtron nebulizer chamber, and its utility was examined on acetylene or hydrogen with air, nitrous oxide, or inert gas (argon or nitrogen) entrained air. The placement of the burner relative to the optical axis of the spectrophotometer (a Nippon Jarrell-Ash Model AA-1 atomic absorption/flame emission spectrophotometer) was effected by means of a compound slide assembly mounted on an optical bench. The single beam-single pass system was arranged in the usual manner. The light beam was modulated at a frequency of 90 Hz by means of a mechanical light-chopper. The flow rates and pressures of the fuels and nebulizing gases were controlled by means of needle valves and were measured by means of calibrated flow meters.

The premixed acetylene or hydrogen flames were formed and extinguished on the burner in much the same manner as that on a welding torch. An acetylene diffusion flame or a hydrogen diffusion flame was first formed at the necessary flow rate (1.0—1.2 l/min for acetylene and 7.2—9.0 l/min for hydrogen). The nebulizing gas (air, nitrous oxide, argon or nitrogen) was then slowly introduced into the nebulizer chamber until the pressure of a nebulizing gas attained 1.5 kg/cm^2, at which point the flow rates of the nebulizing gases were 4.9, 3.8, 4.5, and 5.0 l/min for air, nitrous oxide, argon, and nitrogen respectively. The sample aspiration rates were 8.85, 9.35, 8.90, and 8.95 ml/min with air, nitrous oxide, argon, and nitrogen respectively at the same pressure of 1.5 kg/cm^2. Slight variations in the flow rates and pressures of the nebulizing gases caused only a negligible change in the sample aspiration rates. The flame was extinguished by first terminating the nebulizing gas flow. In particular, a violent flash-back may occur if the acetylene flow is stopped before the nitrous oxide flow. The burner was employed under water-cooling for all the flames. Although the cooling of the burner head promoted salt deposition at the burner slot, the lower temperature of the burner slot markedly reduced the possibility of flash-back.

Performance and Characteristics of a "Multi-flame" Burner

Winefordner *et al.* have used the argon(entrained air)-hydrogen flame[3,4] and the nitrogen(entrained air)-hydrogen flame[5] in atomic fluorescence spectrophotometry and in flame emission spectrophotometry[6] with satisfactory results. On the other hand, Menis and Rains[7] have described that the argon(entrained air)-hydrogen flame with a premixed-type burner system was unstable and that unsuccessful results were obtained for the atomic absorption spectrophotometry of arsenic. In this study, however, not only an argon (entrained air)-hydrogen flame, but also a nitrogen (entrained air)-hydrogen flame, when used with the "multi-flame" burner, was found to be remarkably stable and useful for atomic absorption spectrophotometry.

With this burner, atomic absorptions were measured for various elements. The elements studied were aluminum, bismuth, cadmium, calcium, copper, iron, lead, magnesium, mercury, strontium, tin, and zinc. These elements were chosen for a variety of reasons: efficiency of atomization, background absorption at the wavelength of atomic absorption measurement, susceptibility to chemical interferences, refractory oxide formation, *etc.* The atomic absorptions were measured for each element at various flame compositions and flame heights. Linear analytical calibration graphs were obtained for all the elements and for all the flames. A comparison of the sensitivities for 1% absorption of the elements studied under the optimum experimental conditions for each flame is shown in Table 1.

Salt deposition occurred along the burner slot after a very long period (about five hours) of operation and resulted in flame distortion. The burner clogging depends on the total concentration of solutes in the solutions sprayed into the flame. To minimize this burner clogging, a pure solvent was sprayed into the flame between each measurement. Any remaining particles on the burner slot could easily be cleaned off by passing a thin board through the slot a few times. Air was run out through the burner during the cleaning of the burner slot.

It may be seen from the results shown in Table 1

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[2] R. Friedman and W. C. Johnson, *J. Appl. Phys.*, **21**, 791 (1950).

[3] C. Veillon, J. M. Mansfield, M. L. Parsons, and J. D. Winefordner, *Anal. Chem.*, **38**, 204 (1966).

[4] M. P. Bratzel, R. M. Dagnall, and J. D. Winefordner, *ibid.*, **41**, 713 (1969).

[5] M. P. Bratzel, R. M. Dagnall, and J. D. Winefordner, *ibid.*, **41**, 1527 (1969).

[6] K. Zacha and J. D. Winefordner, *ibid.*, **38**, 1537 (1966).

[7] O. Menis and T. C. Rains, *ibid.*, **41**, 952 (1969).

Table 1. Comparison of the sensitivities for 1% absorption of some elements in the flames with a "multi-flame" burner

Element	Wavelength of measurement (nm)	Sensitivity for 1% absorption (ppm)						
		A	B	C	D	E	F	G
Aluminum	309.2	—	2.2	—	—	—	—	1.1
Bismuth	223.1	0.14	0.8	0.18	1.0	0.10	0.11	0.7
Cadmium	228.8	0.009	0.04	0.02	0.05	0.005	0.006	0.03
Calcium	422.7	0.09	0.03	0.2	0.3	0.2	0.7	0.03
Copper	324.7	0.04	0.2	0.04	0.1	0.04	0.05	0.1
Iron	248.3	0.05	0.1	0.09	0.2	0.1	0.2	0.15
Lead	283.3	0.3	0.9	0.4	1.0	0.3	0.2	0.5
Magnesium	285.2	0.003	0.01	0.01	0.01	0.03	0.02	0.008
Mercury	253.7	1.0	6.0	0.9	3.6	1.1	1.3	15.0
Strontium	406.7	0.07	0.1	0.05	0.6	0.8	2.9	0.2
Tin	224.6	2.6	2.0	0.28	13.8	0.27	0.32	1.2
Zinc	213.9	0.007	0.03	0.008	0.02	0.006	0.009	0.04

A: Air-acetylene flame. B: Nitrous oxide-acetylene flame. C: Air-hydrogen flame. D: Nitrous oxide-hydrogen flame. E: Argon(entrained air)-hydrogen flame. F: Nitrogen (entrained air)-hydrogen flame. G: Results obtained by Slavin.[8)]

that the new "multi-flame" burner can be satisfactorily used with several gas mixtures and that it gives some increase in sensitivity for some elements, compared with those values obtained using a commercial burner.[8)] Furthermore, the hydrogen flame using argon or nitrogen as a nebulizing gas gives significantly better sensitivities for some elements, but severe chemical interferences are likely to occur, because the flame temperature is much lower. The "multi-flame" burner is completely silent in operation, even when using hydrogen as a fuel.

Hydrogen flames with argon(entrained air) and nitrogen(entrained air) would be useful for the atomic absorption spectrophotometric study of some elements which are easily atomized in a low-temperature flame, such as arsenic, bismuth, cadmium, tin, selenium, and zinc.

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8) W. Slavin, "Atomic Absorption Spectroscopy," Interscience Publishers, New York, N. Y. (1968), p. 60.