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# A PROBE SYSTEM FOR SPECTROMETRIC DETERMINATION OF TEMPERATURE AND CONCENTRATION DISTRIBUTIONS IN COMBUSTION GASES

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**Abstract**—Recently a cooled radiation probe has been developed and its performance has been tested for emission utilizing a premixed sodium seeded propane–air flame.

In this paper, a modification of this probe system is reported. By introducing a second probe, the volume between these probes for which emission and absorption measurements are performed may be restricted to any desired size. For sufficiently small volumes, homogenous conditions between the two probes may be assumed which makes the determination of the coefficients a straightforward procedure. The influence of the probe assembly on the flame and the associated spatial resolution of the probe system has been studied by immersing the probes into a homogeneous layer of a premixed sodium seeded propane–air flame.

The results show that the probe system is adequate for spectrometric temperature and concentration measurements in combustion gases regardless of their configuration, as long as regions of steep gradients are excluded.

## NOMENCLATURE

| | |
|---|---|
| $A$, | transition probability for emission; |
| $a$, | line shape factor; |
| $B(T)$, | black body radiation; |
| $c$, | velocity of light; |
| $E$, | energy; |
| $e$, | local emission per unit volume, time, and steradian; |
| $F(T)$, | partition function; |
| $g$, | statistical weight; |
| $I$, | intensity of radiation; |
| $k$, | absorption coefficient; |
| $N$, | number density; |
| $P$, | normalized line profile function; |
| $T$, | temperature; |
| $\alpha$, | absorptivity; |
| $\Delta x$, | thickness of a gas layer; |
| $\Delta\lambda$, | wavelength range covered by the exit slit; |
| $\Delta\lambda_D$, | Doppler broadening half width of a spectral line; |
| $\Delta\lambda_L$, | Lorentz broadening half width of a spectral line; |
| $L$, | wavelength range of a spectral line. |

Subscripts and Superscripts

| | |
|---|---|
| $F$, | flame; |
| $i, j$, | upper and lower state of an atom; |
| L, | reference source; |
| 0, | center wavelength of a spectral line; |
| *, | measured intensities; |
| $\Delta\lambda$, | the covered wavelength range in the exit focus plane of the spectrometer; |
| $\lambda$, | wavelength; |
| $L$, | wavelength range of a spectral line. |

## INTRODUCTION

SPECTROMETRIC methods, as for example, the line reversal and the emission and absorption method have been used for temperature determination in non-luminous flames for many years [1, 2]. In chemistry, spectrometric methods have been used for qualitative and quantitative analysis of sample materials introduced into the flame. In these cases the experimental setup is normally calibrated by seeding the flame with samples of known concentration [3].

In recent years, problems associated with air pollution attracted increasing interest and as a consequence concentration measurements of gaseous species in combustion processes became increasingly important [4–6]. Although it is possible to use gas chromatography and mass spectrometry for analyzing stable species in a flame by sampling with a probe, these methods fail in the case of unstable radicals as for instance OH. On the other hand, spectrometric measurements can be performed without taking a sample by measuring the absorptivity and emissivity of the flame [7].

In order to derive concentrations of certain species in a flame, the corresponding line absorption coefficient and the temperature have to be determined from the measured emissivities and absorptivities.

The side-on measured intensities of a flame are integrated values over the optical path within the flame. In the case of a uniform flame, there exist rather simple relationships between the side-on measured intensities and the emission and absorption coefficients. In the case of non-uniform systems, more elaborate methods have been developed which allow the determination of local emission and absorption coefficients from side-on measured intensities by using Abel inversion techniques provided the system shows a certain symmetry [8–13].

In many combustion systems, strong gradients of temperature and concentration occur only towards the edges of the hot zone. Results derived from measurements, for example, across a flame are strongly influenced by the emission and absorption process in the boundary layer of the flame [14].

Recently a probe has been described which can be used for intensity measurements within a flame regardless of its configuration [15, 16]. In this paper, a double probe system is described consisting of two probes aligned to the same optical axis and facing each other. This probe assembly allows emission and absorption experiments for a preselected optical path length. By introducing two probes into the flame, the influence of the flame boundary can be eliminated by viewing a more or less uniform slab within the flame. Moreover, a reduction of the distance between the probes allows determination of temperature and concentration distributions confined to the hot region of flames.

The performance of the probe system has been checked by determining emission and absorption coefficients of a sodium line at 5890 Å in a uniform temperature-shielded flame as a function of the distance between the probes. The disturbances caused by the probe and the resulting errors in connection with temperature and concentration measurements are discussed in conjunction with limitations of the spatial resolution.

## DESCRIPTION OF THE PROBE SYSTEM

The probes utilized in this study are similar to those described in [15, 16]. Some minor changes are incorporated in the probe design in order to eliminate the earlier experienced difficulties. For reducing the reflectance in the interior of the probe, three equally spaced rings are inserted into the inner tube to form small chambers in which reflected light beams are trapped. Reduction of the opening angle of the probe towards the spectrograph eliminates the dependence of the measured intensity of the flame on the position of probe and flame relative to each other. For this purpose, a 1 cm long diaphragm is used with a constant inside diameter of only 1·5 mm. The inside diameter of the diaphragm of the second probe is approximately 2·5 mm to ensure that the measuring probe defines the volume to be investigated in the flame. In order to avoid strong temperature gradients, especially in front of the diaphragm between the two probes, the diaphragm is made of lava stone, a material with low heat conductivity. During the experiment, the diaphragms are red hot at the tip; but this effect did not contribute to the observed radiation in the investigated wavelength range around 5890 Å.

In the following, the optical setup, which is used in the evaluation of the probe performance, is described. A similar setup may be used for actual measurements.

As indicated in Fig. 1, the probes are mounted on an optical bench. Probe 1 is directly connected with the monochromator by means of a fiber optics. The use of fiber optics is advantageous in practical applications because it makes the location of the probes independent of the location of the optical axis of the monochromator. Thus, it is possible to scan across an area of a stationary combustion source. A high pressure xenon arc lamp is used as a reference source. The arc is imaged onto the inlet of a fiber optics which is connected to probe 2. A lens is introduced between the end of the fiber optics and probe 2 in order to have parallel light passing through probe 2 and the flame onto probe 1. The alignment of the probe system is facilitated by a laser beam. For scanning purposes, the two probes, the corresponding ends of the fiber optics, and the lens should be mounted on the same ground plate in order to avoid changes in the alignment during operation. A 2 m Bausch and Lomb grating spectrometer with a linear dispersion of 4 Å/mm serves as the primary tool. For the measurement of intensities, a rather sensitive photomultiplier (RCA-6845) is employed since the light intensities are extremely small due to the small opening angle of probe 1. The output of the photomultiplier is fed into an amplifier which is connected with a recorder.

The whole setup can be calibrated by replacing the flame with a standard tungsten ribbon lamp. Since a rather large spacing between the probes is needed to accommodate the lamp, the probes are mounted in such a way as to allow for the required distance. Alternatively, the calibration source may replace the xenon arc and losses of intensity are taken into account caused by the various elements between the calibration source and probe 1.

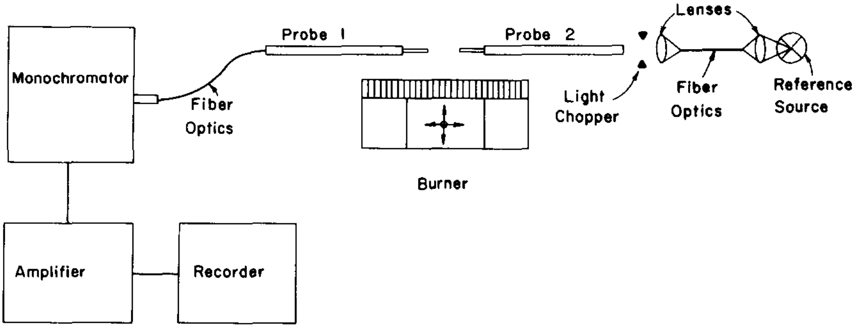

FIG. 1. Optical setup.

## DATA ANALYSIS

Assuming uniform conditions between the probes, the radiative transfer equation integrated over the wavelength range of a spectral line can be brought into the following form

$$\Delta\lambda \times \alpha_{\Delta\lambda_F} = \int_L (1 - \exp[-P_\lambda k_L \Delta x])\, d\lambda = L \times \alpha_{L_F}$$

with

$$\alpha_{\Delta\lambda_F} = 1 - \frac{I^*_{\Delta\lambda_{(F+L)}} - I^*_{\Delta\lambda_F}}{I^*_{\Delta\lambda_L}}. \tag{1}$$

On the left-hand side of equation (1), measurable quantities are gathered. $\Delta\lambda$ refers to the wavelength range covered by the exit slit of the spectrometer, and $\alpha_{\Delta\lambda_F}$ is the absorptivity of the flame determined from measured intensities. In order to determine the line absorption coefficient which can be used for the evaluation of concentrations, the right-hand side has to be calculated for different values of $k_L \times \Delta x$. The measured left-hand side then can be compared with the calculated right-hand side. In order to determine the integral, the profile function $P_\lambda$ has to be known. The line profile of a spectral line in a flame under atmospheric pressure is described by the so-called Voigt profile, a superposition of a Doppler and Lorentz broadened profile. Whiting [17] developed for the Voigt profile an analytical expression containing the Doppler and the Lorentz broadening half width of the line. The connection between the Lorentz broadening half width $\Delta\lambda_L$ and the Doppler half width $\Delta\lambda_D$ is given by the line shape factor

$$a = \frac{\Delta\lambda_L}{\Delta\lambda_D}\sqrt{(\ln 2)}. \qquad (2)$$

Semi-empirical expressions for the line shape factor are given in the literature for different atoms and molecules and for different flames [3, 18]. The Doppler half width depends on the temperature of the flame. Thus, description of the line profile requires knowledge of the temperature distribution. It can be shown that in the case of a uniform flame, the temperature is determined by the ratio of the absolute intensity to the absorptivity of the flame using Kirchhoff's and Planck's law.

In Fig. 2, the values of the integral $\alpha_{L_F} \times L$ as a function of $k_L \times \Delta x$ for temperatures of $T_F = 2000$ and 2200°K are shown for the sodium line at 5890 Å. The line shape factor for this line is according to the literature $a = 0{\cdot}815$ [19]. The wavelength interval for the integration is taken as $L = 0{\cdot}48$ Å. The introduced errors by cutting off the line wings are small. They are a weak function of the temperature and also of the product $k_L \times \Delta x$. It can be seen that the temperature has only a weak influence on the integral.

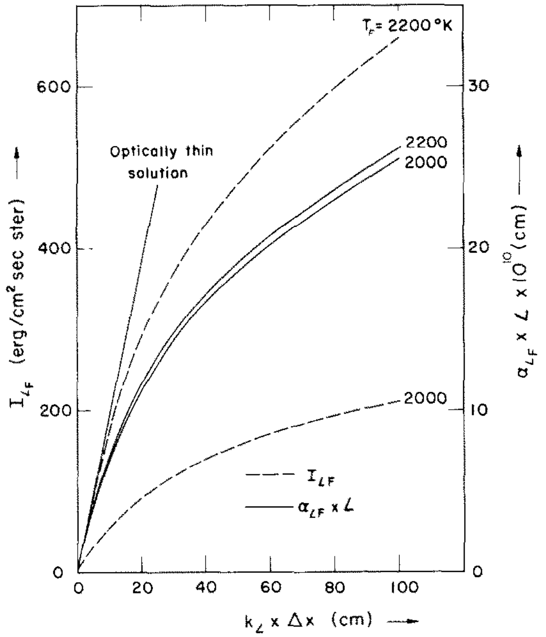

FIG. 2. Intensity $I_{L_F}$ and absorptivity $\alpha_{L_F}$ of the sodium line at 5890 Å as a function of $k_L \times \Delta x$.

From the radiative transfer equation, the following expression for the intensity of the flame can be derived

$$I_{F_L} = B_\lambda(T_F)\int_L (1 - \exp[-P_\lambda k_L \Delta x])\,d\lambda. \qquad (3)$$

The resulting curves as a function of $k_L \times \Delta x$ are also shown in Fig. 2. They show a strong influence of the temperature on the intensity of the flame caused by the multiplication of the integral with the black body function $B_\lambda(T_F)$. The straight line refers to the optically thin solution.

The number density of atoms or molecules involved in the investigated transition is

$$N = \frac{8\pi c}{\lambda_0^4}\frac{1}{g_i A_{ij}} \times k_L \frac{F(T_F)}{\exp[-E_j/kT_F]}. \qquad (4)$$

For the sodium line at 5890 Å with $g_i A_{ij} = 1{\cdot}8 \times 10^8$ [$\mathrm{s}^{-1}$] [3], $E_j = 0$, and $F = 2{\cdot}0$ [20], the number density of sodium atoms becomes

$$N_{\mathrm{Na}} = 6{\cdot}82 \times 10^{17} \times k_L \left[\frac{1}{\mathrm{cm}^3}\right]. \tag{5}$$

### TESTING OF THE PROBE SYSTEM

There are three important ways in which such a probe system may distort the measured results. The probe system may distort the velocity distribution and, therefore, the concentration distribution in the flame; it may influence the temperature distribution and finally, combustion gases may diffuse into the probe and change the thickness of the investigated slab. The latter effect is eliminated by blowing a small amount of argon through both probes during the actual experiment.

For a check of the two other effects, emission and absorption coefficients of the sodium line at 5890 Å using a uniform slab are determined for different concentrations of sodium as a function of the distance between the probes. Thus, any deviation from constant values indicates the influence of the above-mentioned effects.

An almost uniform radiating gas slab is produced by a Meker type burner [15]. An inner rectangular part of the burner is supplied with propane and air which are premixed in a mixing chamber. A portion of the air stream is passed through an atomizer containing a sodium solution for seeding the flame with sodium. The inner luminous flame is surrounded by a non-luminous propane–air flame in order to avoid the temperature gradients at the edges of the inner flame. There is still a sodium concentration gradient at the edges. The thickness of this non-uniform layer increases with increasing distance from the burner outlets. Therefore, the experiments are performed at a height of only 12 mm above the burner outlets. The oxidator ratio and the flow rates are identical for both flames. The gases are premixed almost stochiometrically. The seeding provided by the atomizer seems to be a function of the available NaCl solution in the atomizer. Fluctuations of the sodium supply and of the flame conditions are checked by measuring the line intensity of the sodium line before and after each test series. A test series is rejected if a difference of more than 3 per cent occurs.

The sodium line is focused into the exit slit by turning the grating of the spectrometer while the flame is burning. For the evaluation of the data, the physical exit slit width has to be known. The slit width is measured with a microscope as a function of the reading of the micrometer which allows the setting of a desired slit width. Using the dispersion of the instrument $D_{\mathrm{L}} = 4$ Å/mm, the covered wavelength range may be calculated.

For the adjustment of the exit slit width for total line intensity measurements, the intensity of the sodium line in the flame is measured as a function of the slit width with the centerline of the exit slit coinciding with the line center.

The measured relative intensities $I_{\Delta\lambda_F}$ as a function of $\Delta\lambda$ show that for the highest sodium concentration used, the intensity changes becomes small above $\Delta\lambda = 2{\cdot}4$ Å.

There is a constraint on the exit slit width which should be chosen as small as possible in order to increase $\alpha_{\Delta\lambda_F}$ according to equation (1). To increase the sensitivity of the absorption measurements, an instrument with high resolution is required. On the other hand, the errors incurred by neglecting the wings of the line have to be kept small. For the discussed measurements, $\Delta\lambda$ is chosen to be 2·4 Å. The error introduced in this way is approximately 5 per cent. This error is partially offset because in the calculation of the integral in equation (1) the wings of the line are also neglected.

### EXPERIMENTAL PROCEDURE

The optical alignment is not disturbed by the presence of the flame which is checked by calibrating the system with and without the flame using a standard tungsten ribbon lamp as a calibration source. The same check is applied for adjustment of the argon flow in the probes. Possible influences of the flame on the second probe are checked by recording the signal of the reference source with and without flame. Since the test shows a measurable influence of the flame on the second probe, the intensity of the reference source has to be determined under actual test conditions. In the described experiment, this check is accomplished by interrupting the sodium supply for the measurement of the intensity of the reference source. In an actual experiment, the species which are of interest cannot be eliminated. This difficulty can be resolved by measuring the intensity of the reference source close to the spectral line where no appreciable absorption occurs.

The intensity of the flame, the intensity of the flame and reference source, and the intensity of the reference source alone are measured as a function of the distance $\Delta x$ between the probes. All quantities are measured during a continuous run at various distances of the probes. The gap $\Delta x$ is monitored by moving the second probe towards the first one on the optical bench and adjusting the burner to the centerline between the two probes.

Measurements are performed for different sodium concentrations. The concentrations are varied by changing the NaCl concentration in the solution in the atomizer in steps of a factor of two so that the relative concentration distribution can be checked.

### DISCUSSION OF THE RESULTS

Measurements taken with both probes outside the flame do not disturb the flame and, therefore, they are considered as reference points. As a second reference point, a distance is chosen so that the two probes are immersed into the shielding flame but still outside the luminous region of the flame. This reference point indicates any changes in the probe system caused by the flame. For these points, the temperatures $T_F$ are determined from the ratio of the intensity of the flame $I_{\Delta\lambda_F}$ to the absorptivity $\alpha_{\Delta\lambda_F}$ using Kirchhoff's and Planck's law. Since the intensity of the xenon arc is very high, the intensity of the flame $I_{\Delta\lambda_F}$ can be neglected in the determination of $\alpha_{\Delta\lambda_F}$.

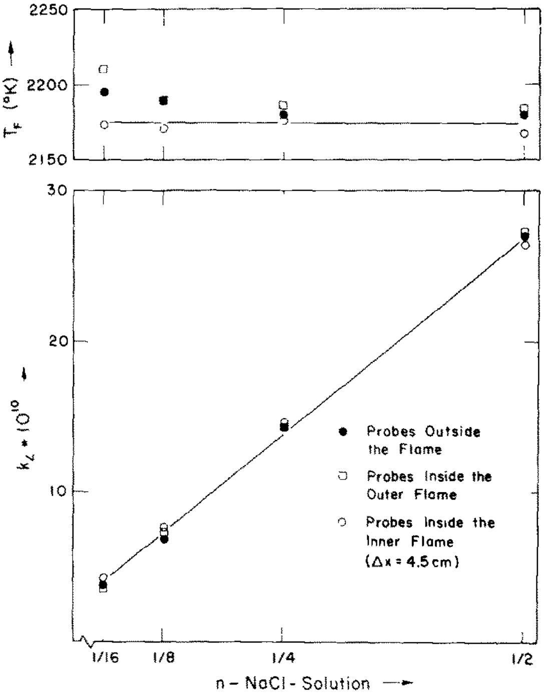

FIG. 3. Line absorption coefficients and temperatures for different sodium concentrations.

The resulting temperatures $T_F$ are given in Fig. 3 as a function of the relative concentration of sodium. A third measurement with $\Delta x = 4{\cdot}5$ cm, a distance at which the concentration gradients at the edges of the luminous part in the flame are excluded and at which the changes introduced into the flame by the probes are believed to be very small is also shown. In the investigated concentration range, the temperatures are almost constant (2175°K). The spread of the data is approximately $\pm 10$°K except for the lowest concentration for which the spread is approximately 40°K. This is probably caused by the increasing uncertainty in the absorption measurements with decreasing degree of absorption. The measurement inside the luminous flame shows the lowest values

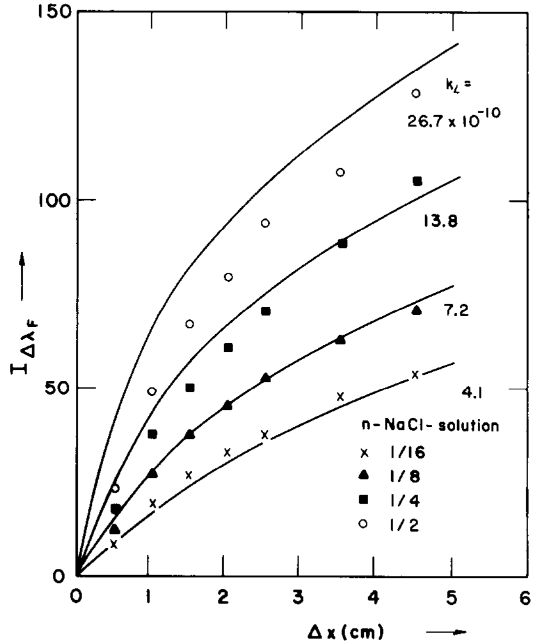

FIG. 4. Measured and calculated (solid lines for $T_F = 2175°K$ with corresponding absorption coefficients) sodium line intensities (5890 Å).

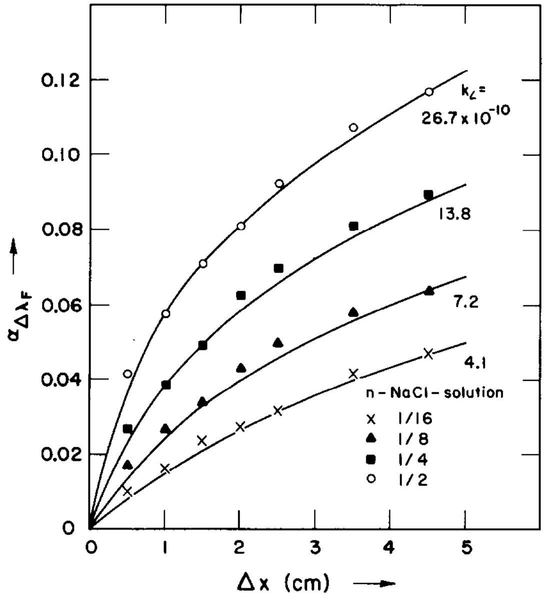

FIG. 5. Measured and calculated (solid lines for $T_F = 2175°K$ with corresponding absorption coefficients) sodium line absorptivities (5890 Å).

which are probably due to a small influence of the cooling effect of the probes on the temperature measurements. Measurements of the thickness of the radiating layer bear an uncertainty of $\pm 2{\cdot}5$ mm in the case of the two reference points whereas the uncertainty drops to $\pm 0{\cdot}25$ mm for all the other points.

The line absorption coefficient $k_L$ is determined with the help of equation (1) using $T_F = 2175°K$. In Fig. 3, the resulting absorption coefficients $k_L$ are shown as a function of the relative concentration of sodium. The values of the individual measurements are close together and can be represented by a straight line indicating that for these points at least the relative concentration distribution is properly recorded by the probes.

In Figs. 4 and 5, the measured relative intensities $I_{\Delta\lambda_F}$ and absorptivities $\alpha_{\Delta\lambda_F}$ are shown as a function of $\Delta x$ for different concentrations. Using the absorption coefficients from Fig. 3 and a temperature of $T_F = 2175°K$, the relative intensities and absorptivities are calculated as a function of $\Delta x$ applying equations (1) and (3). These results are represented by the solid lines in Figs. 4 and 5. Any deviation from these lines shows the influence of the probe system on the flame. In the case of the $\alpha_{\Delta\lambda_F}$ values, only small deviations are observed, especially for low sodium concentrations. The flame intensities, however, exhibit larger deviations, especially for higher concentrations. Since $\alpha_{\Delta\lambda_F}$ is almost independent of temperature, the deviations in Fig. 5 are due to disturbances of the concentration distribution caused by the probes. Since $I_{\Delta\lambda_F}$ is a function of the concentration and of the temperature, the deviations in this case show the coupled effect of concentration and temperature distortions.

Temperatures determined from the ratio of these two quantities are independent of concentration and show, therefore, the cooling effect of the probes alone. In Fig. 6, temperature distributions as a function of $\Delta x$ are shown. The horizontal line refers to the reference temperature from Fig. 3. The temperatures are grouped around this temperature with a spread of

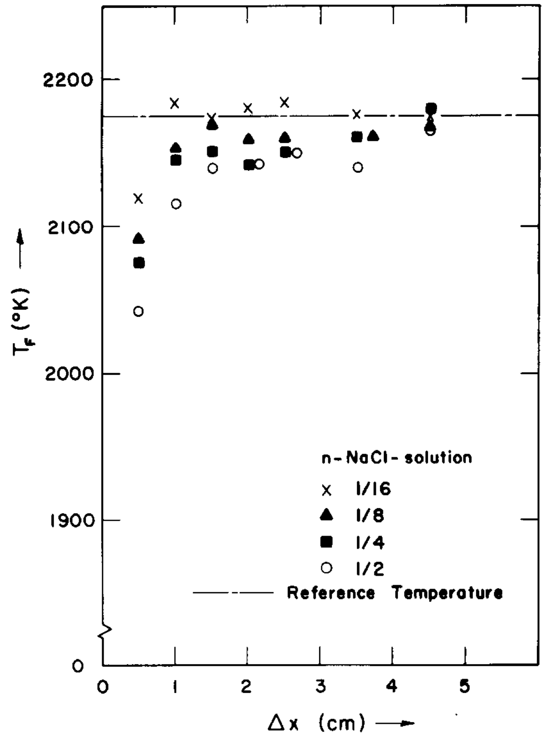

FIG. 6. Flame temperatures $T_F$ as a function of the distance $\Delta x$ between the probes.

approximately ±20°K for $\Delta x \geq 1{\cdot}5$ cm. The spread increases with decreasing distance between the probes because of the increasing uncertainty caused by the small absorptivity. It is advantageous for the measurement of temperature distributions to increase the absorptivity by using only the center portion of the spectral line. Below $\Delta x = 1$ cm, the temperatures decrease very rapidly, reflecting the cooling effect of the probes. The results show that the apparent temperatures for low concentrations are the highest and vice versa. Despite the fact that these deviations are within the accuracy of the method itself (±20°K), there seems to be a trend indicating the influence of the temperature distribution caused by the probes as well as the influence on the radiative transfer for different amounts of sodium.

Using the actually measured temperatures and $\alpha_{\Delta\lambda_F}$ values, the line absorption coefficients $k_L$ as a function of $\Delta x$ are calculated (Fig. 7) from equation (1) via an iteration procedure. For low concentrations, the $k_L$ values are slightly above the reference values (horizontal line) and the probes cause only a minor disturbance of the concentration distribution. This effect can be observed as an increase of the measured intensity with decreasing gap between the probes. The effect is substantially reduced with increasing concentration. Data for $\Delta x = 0{\cdot}5$ cm are always relatively high, probably caused by the combination of the previously-mentioned effect of concentration change and by the strong temperature drop in this range. Except for the data at $\Delta x = 0{\cdot}5$ cm, the data spread is approximately ±5 per cent.

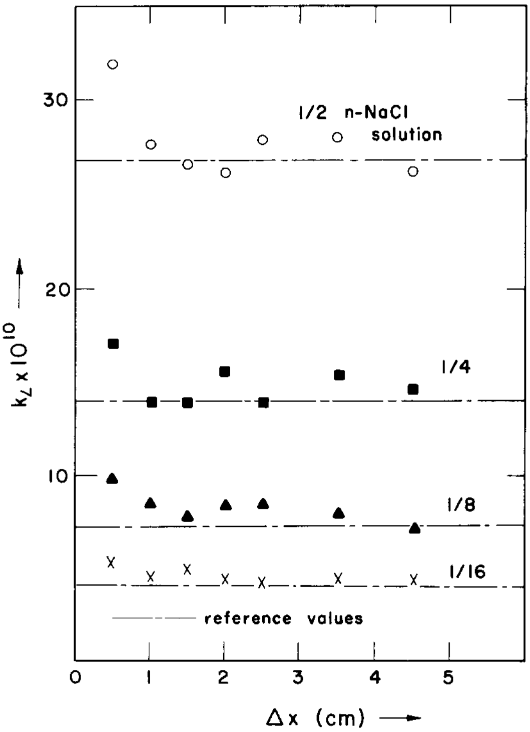

FIG. 7. Line absorption coefficients $k_L$ of the sodium line at 5890 Å as a function of the distance $\Delta x$ between the probes.

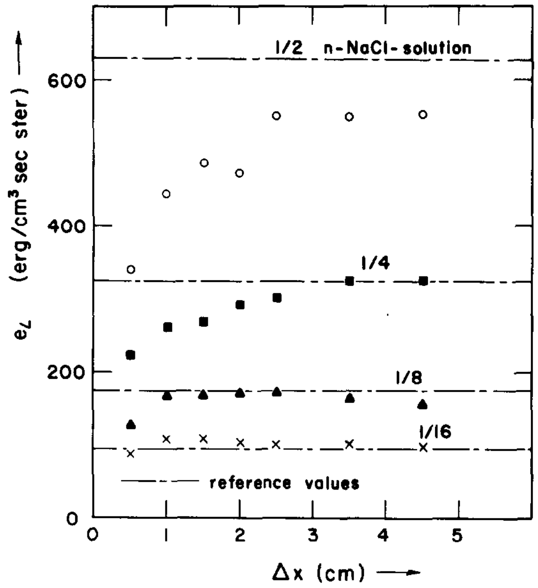

FIG. 8. Line emission coefficients of the sodium line at 5890 Å against the distance $\Delta x$ between the probes.

The line emission coefficients represented in Fig. 8 show a strong deviation from the corresponding reference values at high concentrations. Since these values are strongly influenced by the temperature, they reflect more or less the temperature distribution (see Fig. 6). The deviations are enhanced in the case of the line emission coefficients since the intensity is an exponential function of the temperature of a radiating gas. In contrast to the previous results, the influence of the probes on the flame is not restricted to small distance between the probes for high concentrations.

## CONCLUSIONS

The evaluation of the probe system with respect to its performance for concentration and temperature measurements in flames discloses two important effects of the probes on the flame. The influence on the flow field and, therefore, on the concentration is weak and only observed at rather small sodium concentrations and also for small distances below 1 cm between the probes. Since the absorptivity decreases with decreasing concentration and decreasing distances between the probes, the accuracy of the absorption measurement decreases too. Thus, for concentration measurements employing absorption data, the distance between the probes should be larger than 0·5 cm and the measured absorptivities should be in excess of 2 per cent. The absorption coefficients derived from absorptivities larger than 2 per cent show a spread of ±5 per cent. The accuracy is expected to decrease again for very large absorptivities because of the non-linear relationships between the absorptivity and the line absorption coefficient (see Fig. 2). Because of the errors in connection with the data evaluation (determination of $L$, $\Delta\lambda$, $a$) and the uncertainty in the transition probabilities, it is believed that the total accuracy of concentration measurements is approximately ±10 per cent in the case of sodium. For a rough estimation of the concentration, it is sufficient to measure the absorptivity $\alpha_{\Delta\lambda_F}$ because $k_L$ is only weakly influenced by the temperature so that a mean temperature can be estimated. Using a high intensity comparison source, the intensity of the flame can be neglected in the absorption equation. Thus, for concentration measurements, the intensity of the flame and reference source has to be measured as a function of the position of the probes in the flame. For a fixed distance between the probes, the intensity of the reference source alone is constant so that this quantity has only to be measured once. If the volume concentration is desired, an additional emission experiment is required because the temperature distribution has to be known. This is also necessary for the determination of molecule concentrations.

The measured temperatures are influenced by the cooling effect of the probes on the investigated radiating layer. There is some evidence that the concentration of sodium influences the temperatures also because of the effect of the temperature distribution on the radiative transfer for different concentrations. The influence of the temperature profile between the probes becomes more and more important with decreasing distance between the probes. Simultaneously, the accuracy of the temperature determination decreases because of decreasing absorptivity. Down to $\Delta x = 1$ cm, the probe system is useful for temperature measurements providing an accuracy of approximately $\pm 1 \cdot 5$ per cent at temperatures around 2200°K.

The line emission coefficients show large errors especially for large concentrations. This is caused by the strong dependence of line emission coefficients on temperature. The use of the line emission coefficient for concentration measurements should, therefore, be restricted to cases which match optically thin conditions. The temperature has then to be determined with high accuracy by using a different strongly absorbing line.

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## UN SYSTEME DE SONDE POUR LA DETERMINATION SPECTROMETRIQUE DES DISTRIBUTIONS DE TEMPERATURE ET DE CONCENTRATION DANS DES GAZ DE COMBUSTION

**Résumé**—On a présenté récemment une sonde refroidie par rayonnement et on a testé ses performances pour l'émission par utilisation d'un prémélange propane–air et sodium en dispersion.

On traite dans cet article d'une modification de ce système de sonde. Par introduction d'une seconde sonde, le volume entre ces sondes pour lequel ont été faites les mesures d'émission et absorption peut être réduit à taille voulue quelconque. Pour des volumes suffisamment petits, on peut supposer des conditions d'homogénéïté entre les deux sondes ce qui rend correcte la détermination des coefficients. L'influence de l'ensemble des sondes sur la flamme et la résolution spatiale associée du système de sonde ont été étudiés en immergeant les sondes dans une couche homogène de flamme d'un prémélange propane–air avec dispersion de sodium.

Les résultats montrent que le système de sonde est adéquat pour des mesures spectrométriques de températures et de concentration dans des gaz en combustion indépendantes de leur configuration tant que sont exclues les régions de forts gradients.

## EIN SONDENSYSTEM ZUR SPEKTROMETRISCHEN BESTIMMUNG VON TEMPERATUR- UND KONZENTRATIONSVERTEILUNGEN IN VERBRENNUNGSGASEN

**Zusammenfassung**—Kürzlich wurde eine gekühlte Strahlungssonde entwickelt und ihre Leistung für Emission geprüft unter Benützung einer vorgemischten Propan-Luft-Flamme mit Natriumzugabe.

Hier wird von einer Änderung dieses Sondensystems berichtet. Durch Einführung einer zweiten Sonde kann das Volumen in dem Emissions- und Absorptionsmessungen vorgenommen werden zwischen diesen Sonden auf jeder gewünschten Grösse eingeschränkt werden. Für hinreichend kleine Volumen können einheitliche Bedingungen zwischen den zwei Sonden angenommen werden, was die Bestimmung der Koeffizienten vereinfacht. Der Einfluss der Sondenanordnung in der Flamme und die zugehörige räumliche Auflösung des Sondensystems wurden geprüft, indem die Sonden in ein homogenes Medium aus einer vorgemischten Propan-Luft-Flamme mit Natriumzugabe gebracht wurden.

Die Ergebnisse zeigen, dass das Sondensystem gleich gut ist für spektrometrische Temperatur- und Konzentrationsmessungen in Verbrennungsgasen ohne Rücksicht auf räumliche Form, so lange Bereiche steiler Gradienten ausgeschlossen werden.

# СИСТЕМА ДАТЧИКОВ ДЛЯ СПЕКТРОМЕТРИЧЕСКОГО ОПРЕДЕЛЕНИЯ РАСПРЕДЕЛЕНИЙ ТЕМПЕРАТУРЫ И КОНЦЕНТРАЦИИ В ГОРЯЩИХ ГАЗАХ

**Аннотация**—Недавно был разработан охлаждаемый датчик излучения, характеристики которого были испытаны на излучении пропано-воздушного пламени с внесенным в него перемешанным натрием. В данной работе описывается модифцированная система такого датчика. Путём ввода второго датчика объём между ними, для которого производятся измерения излучения и поглощения, можно ограничить до нужного размера. Можно сделать предположение, что для достаточно малых объёмов между датчиками имеют место однородные условия, и это весьма упрощает определение коэффициентов. Влияние системы датчиков на пламя и связанное с этим пространственное разрешение системы исследовалисть путём погружения датчиков в гомогенный слой пропано-воздушного пламени с внескнным в него перемешанным натрием.

Результаты покавывают, что систему датчиков независмо от их конфигурации можно использовать при спектрометрических измерениях температуры и концентрации в горящих газах, исключая области больших градиентов.