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INFRARED RADIATION MEASUREMENTS OF COMBUSTION GASES

University of California at Davis

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INTRODUCTION

Knowledge of the infrared radiative properties of rocket exhaust gases is required in many applications. Examples include the prediction of radiative heating to the base regions of multi-rocket-engine vehicles and the long-range detection of ballistic missiles. The magnitude and characteristics of this infrared radiation depend on the flame composition and temperature.

Analytical studies of the radiative heating from rocket exhaust plumes have indicated the need for complete and accurate spectral emission and absorption data. This is due to the fact that existing theories for predicting infrared radiation from high temperature gases are based on highly idealized physical models. Consequently, experimental measurements are needed to guide applications of the theories and to confirm their validity.

The objective of the present study is to obtain the spectral characteristics of a number of common combustion products under a variety of accurately known thermodynamic and optical conditions. An experimental apparatus for this purpose has been designed and constructed. The central component is a graphite resistance furnace with an inert ceramic tube liner for the containment of high-temperature gases. A beam of radiation from a high-temperature source is directed through a known length of test gas in the center region of the furnace. A monochrometer on the opposite end of the furnace is used to measure the amount of energy absorbed as a function of wave length.

The laboratory program was initiated using carbon monoxide. Measurements of the spectral absorptivities up to 1500°K have been reported.[1] These included

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1 "Infrared Radiation of Carbon Monoxide at High Temperatures," M. M. Abu-Romia, Institute of Engineering Research, University of California, Berkeley, Report No. TS-65-5, Contract NAS 8-11468, Sept. 1965.

data for the 4.67 micron fundamental band at path lengths of 1, 5, 10, and 20 cm and temperatures of 300, 600, 900, 1200, and 1500° K over the pressure range of 1/4 to 3 atmospheres. For the first overtone band absorption was found to be significant only for a path length of 20 cm at pressures of 1, 2, and 3 atmospheres for the same temperatures.

As a result of the move of the principal investigator from the Berkeley Campus to the Davis Campus of the University of California the project was transferred to the Davis Campus. Since it was necessary to disassemble the high-temperature spectral absorption apparatus for moving, it was decided to review the original design before reassembly. The particular objective of this was to see if modifications could be made to permit absorption measurements at higher temperatures.

REASSEMBLY OF INFRARED SPECTRAL ABSORPTION SYSTEM

Two possible arrangements were considered -- one with the furnace axis horizontal and the second with the furnace axis vertical. In the evaluation of these two alternatives it became apparent that the advantages of vertical mounting were marginal (the main one being lower tensile stress in the ceramic liner of the furnace). In view of this and the inconvenience and complications associated with a vertical arrangement, it was decided to mount the furnace so that its axis was horizontal.

The infrared spectral absorption system will be assembled as shown in Figure 1. It consists essentially of a high-temperature source (a water-cooled globar unit), a graphite resistance heated tube furnace in which the test gas is heated, and a prism-type spectrometer. The latter is referred to as a monochrometer since the energy in only a small wave length region of the spectrum produced by the prism is directed to the sensing element at any time. As indicated this system will be mounted on an optical bench.

The box-like optical channel connecting the source and furnace is shown in Figure 2. The connection between the furnace and the monochrometer is similar. This particular design was selected so that the assembly holding the test-cell windows would be independent. When the covers of the optical channels are removed, the test-cell assembly can be easily removed and the test path length changed.

The detailed design of the test-cell assembly is shown in Figure 3. The test-path length is defined by a zirconia tube 1.25 inch in outer diameter. Sapphire windows are held in contact with the ends of this tube by similar sized tubes inserted from each end of the furnace. These tubes are brazed to Kovar tubes which in turn are mounted to aluminum end pieces.

Platinum washers are used between the sapphire windows and the zirconia tubes to provide sealing of the test chamber. Although this type of seal has been found to be satisfactory, smaller tubes are mounted concentrically inside the 1.25 inch in diameter tubes so that transparent gas can be forced past the platinum washer seals. Consequently, if a small amount of test gas leaks out, it will be flushed out by this transparent gas flow.

The inner section of the test-cell assembly is kept in position by a larger zirconia tube which extends over the sapphire windows. A bellows is incorporated into the end facing the monochrometer. Spacer lengths will be made so that it is necessary to extend this bellows to install the test assembly in the furnace. In this way the zirconia tube assembly will be under compression. This serves to hold it in position and provide the pressure necessary for sealing.

Optical-test path lengths can be varied by inserting the desired length of zirconia tube in the center between the sapphire windows. Appropriate changes in the spacers just outside the furnace will also be required.

Components for the optical channels and test-cell assembly are now being fabricated. They should be completed toward the end of the next quarter. After assembly of the system effort will first be directed to measurement with carbon monoxide.

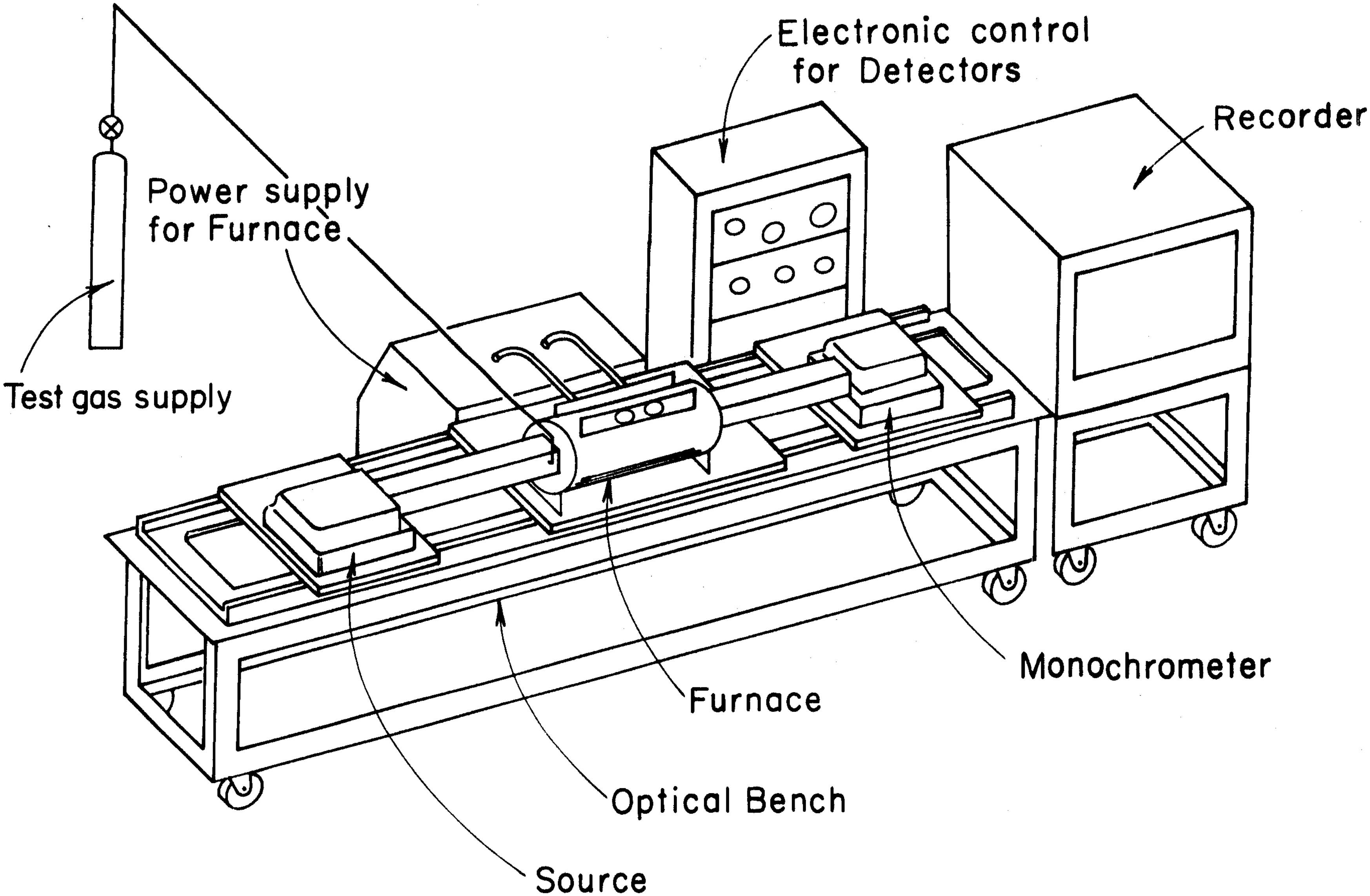

Fig.1 INFRARED SPECTRAL ABSORPTION SYSTEM

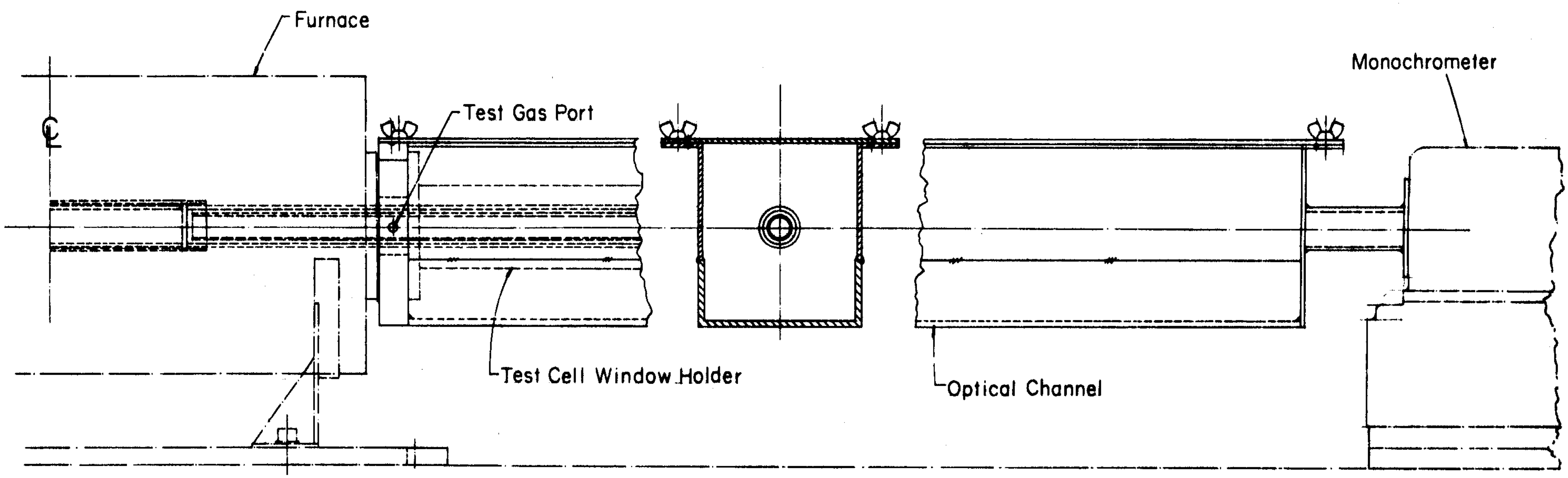

FIG. 2 FURNACE–MONOCHROMETER OPTICAL CHANNEL

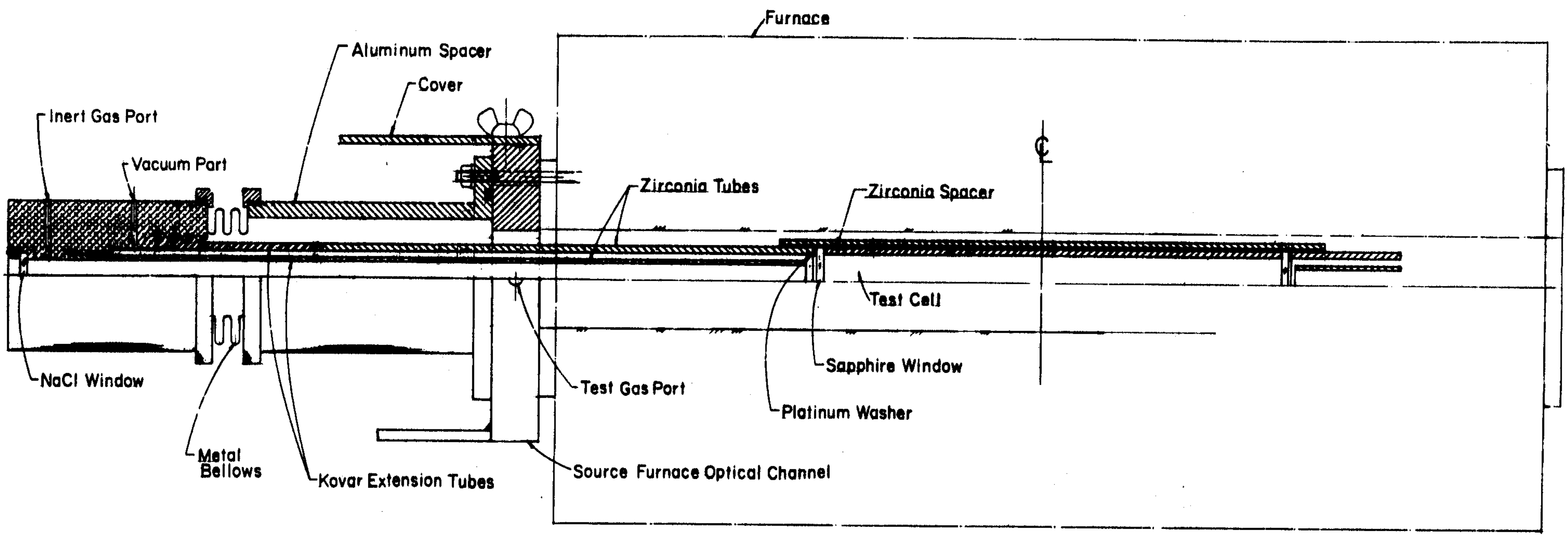

FIG. 3 TEST CELL ASSEMBLY