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[54] **GENERAL PURPOSE ANALYZER FOR PLASMA MEDIA**

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[58] **Field of Search** ..... 23/253 PC, 253 R, 232 R, 23/254 R; 250/281, 282, 283, 288

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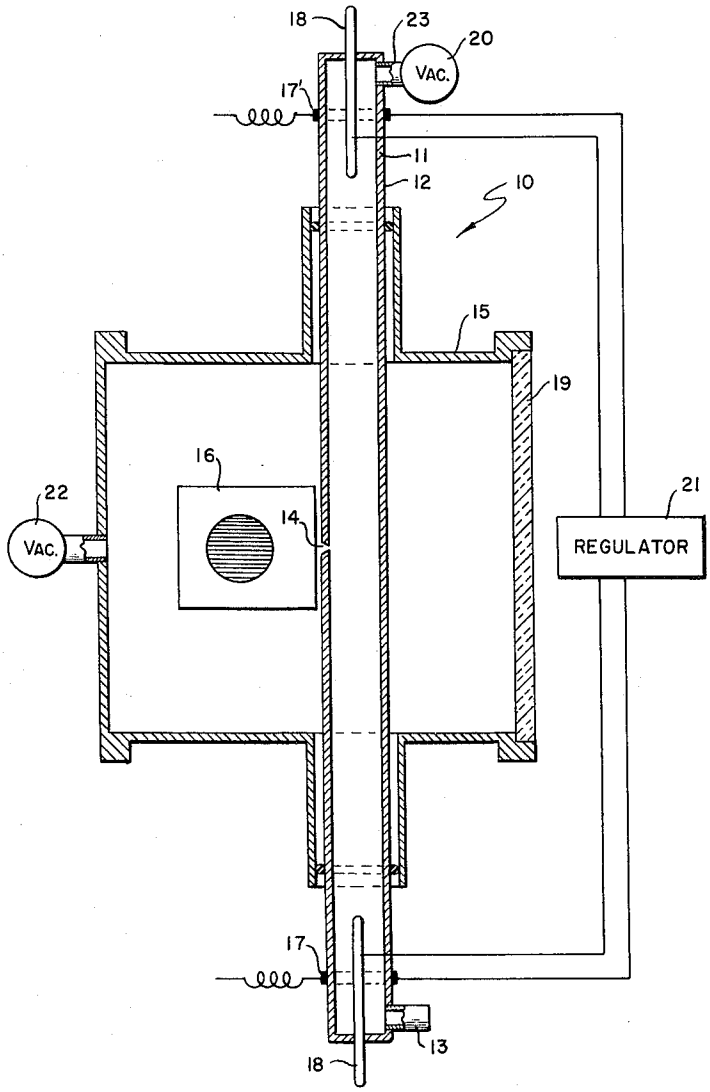
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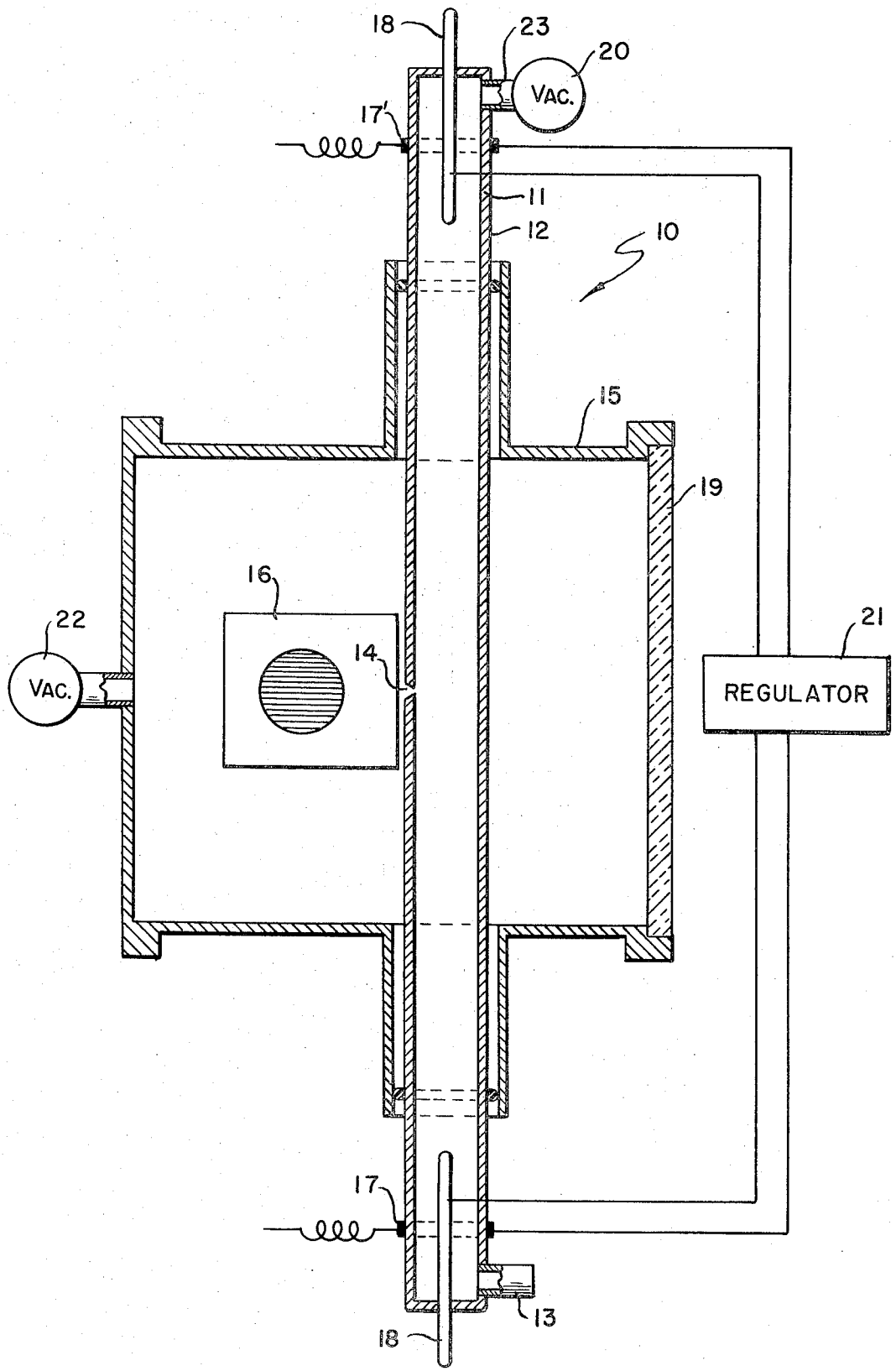
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[57] **ABSTRACT**

A hollow cylinder within an outer jacket having plasma identifying means therein is used to study chemical reaction samples adiabatically. The cylinder contains a sampling port adjacent the plasma identifying means, and heating means to control the temperature profile of the cylinder.

10 Claims, 1 Drawing Figure




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VAC.
17'
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VAC.
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REGULATOR
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GENERAL PURPOSE ANALYZER FOR PLASMA MEDIA

BACKGROUND OF THE INVENTION

In recent years much attention has been given to the study of the chemical reactions occurring during combustion and lasing. This interest has led to the development of apparatus useful in that study. Apparatus commonly used in studying these reactions fall into two categories, the static flow and the continuous flow arrangement.

Gas chromatography has been the chief diagnostic technique employed to analyze reaction samples obtained by the static flow arrangement. When using this technique, batch samples are taken from the reaction vessel and introduced into the chromatograph. The sample is separated into its constituent parts on the basis of adsorptive properties and detected as it emerges from the chromatograph. The major drawback of this technique is the amount of time involved in obtaining the sample and then introducing it into the chromatograph. During this time period the unstable species of the reaction sample are lost and trace quantities of other species are adsorbed by the walls of the sampling probe. The use of the probe and the time factor required also results in a loss of heat. Because of these problems, samples obtained do not accurately reflect the reaction actually occurring.

Another technique often used with the static flow arrangement to analyze the reaction plasma is mass spectrometry. This technique involves combining the static sampling system with a rapid scanning mass spectrometer. The main disadvantage of this system is its inability to separate and examine the individual stages of the plasmas. It is, therefore, difficult to distinguish the reactions occurring in one stage from those occurring in another stage.

Many of the difficulties encountered in the static systems have been overcome by sampling in a continuous flow arrangement. However, a major impediment to the success of this type of system has been the use of probes to sample the plasma. The probes, usually produced from quartz, are introduced into the reaction chamber forming a path between the chamber and an analyzing instrument. While the use of a continuous flow reaction chamber with a probe is more advantageous than the static system, it is far from ideal for several reasons. First, most samples contain both stable and unstable species. During the time that the sample flows from the vessel into the analyzing instrument, usually about 2 seconds, the species react with one another so that the unstable species are lost and cannot be detected by the analyzing instrument. Second, the probe disturbs the aerodynamic flow of the plasma front. The change of the flow to the probe alters the original concentration gradients of the species. Third, the probe acts as a heat sink, reducing the temperature of the area surrounding the probe. Thus, any sampling is accomplished non-adiabatically. The nature of the reaction found in the sample is therefor different from that of the actual reaction occurring.

All of the problems discussed prevent the study of sample reactions that accurately reflect the true reaction. The accuracy of any data obtained using the prior art's apparatus is therefor in question.

SUMMARY OF THE INVENTION

The present invention relates to a novel apparatus useful in the study of reaction plasma. More specifically, it contemplates the use of a continuous flow reaction vessel having a sampling port adjacent a plasma analyzer. By controlling the temperature gradient of the vessel so that the desired reaction or desired reaction stage occurs adjacent the sampling port, samples of the reaction gases are allowed to enter the plasma analyzer directly. This obviates the need for any probes. The amount of time required for the sample to flow from the vessel into the analyzer is about 3–5 microseconds. It is also possible to quench the unstable species of the reaction and prevent those specices from colliding with any other species or the wall of the analyzer by controlling the pressure in both the vessel and the analyzer. Furthermore, the sampling can be accomplished adiabatically because the temperature profile of the reaction vessel is controlled.

It is therefor an object of the invention to provide a novel apparatus for studying plasma, in which the reaction sample analyzed closely resembles the reaction actually occurring.

It is another object of the invention to provide a system in which the samples can be obtained without the use of probes.

Another object is to provide an apparatus capable of separating the individual reaction stages.

A further object of the invention is to provide an apparatus that allows the study of the reaction to be performed adiabatically.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE illustrates a cross-section of the novel apparatus for analyzing plasma.

DETAILED DESCRIPTION

The novel apparatus, **10,** comprises an upright hollow cylinder **11** having an outer jacket, **15,** sealingly engaged about it. The outer jacket is connected to a vacuum source, **22.** Inside the outer jacket a plasma identifying means, **16,** or plasma analyzer is located. A typical plasma identifying means is a spectrometer, such as a Time-Of-Flight mass spectrometer or microwave spectrometer. The spectrometer is located adjacent and in close proximity to a cone shaped sampling port, **14.** The port is very small, in the order of **25** microns. The outer jacket can also be equipped with a viewing port, **19.**

The hollow cylinder can be produced from any transparent insulating material. A preferred material, however, is quartz. In order to control the temperature profile within the cylinder lower heating means **17** and upper heating means **17'** are provided. The heating means, typically metallic bands or silver print paint, are connected to an electrical energy source, not shown, and a heat regulator, **21,** that is used to control the heat flow from the heating means **17** and **17'**. Regulator **21** is also connected to temperature probes **18.** Thus, any heat loss can be detected and compensated for by providing additional heat from the appropriate heating means. In order to control the temperature profile of

the entire cylinder, the cylinder is coated with an electrically conductive material, **12,** such as stannic oxide, silver or any other conductive coating that can withstand temperatures up to 1,000°C. With the use of this coating and the upper and lower heating means the temperature profile within the entire cylinder can be controlled.

Located at either end of the cylinder is a pressure source. If the pressure desired within the cylinder is less than atmospheric the pressure source will consist of a vacuum pump, **20,** connected to the exhaust means, **23.** If the pressure is to be above atmospheric a pressure source, such as a compressor may be located at the inlet, **13,** or the pressure may be obtained by increasing the flow rate of the reactant gases.

The apparatus operates as follows. Both the cylinder, **11,** and the outer jacket are placed at the appropriate pressure. Typical pressures used in the cylinder range from 1×10^{-2} torr to 2 atm depending upon the reaction to be sampled. In order to force a sample of the reactants through the sampling port, **14,** a pressure drop of about **5** orders of magnitude is needed between the cylinder **11** and the outer jacket **15.** Therefore, pressures commonly used in the outer jacket range from 1×10^{-5} torr to 1×10^{-8} torr. Next the reactants are introduced into the cylinder through inlet, **13** and the temperature profile is obtained so that the desired reaction occurs adjacent the sampling port. This is accomplished by regulating the heat flow into the heating means **17** and **17'** until the desired reaction takes place adjacent the sampling port. Due to the pressure drop, the reaction plasma are forced through the sampling port and analyzed.

The novel apparatus, thus, permits the study of reaction plasma without using any probes. The plasma enters the analyzer so quickly, within 3 to 5 microseconds, that virtually no wall collisions take place. Furthermore, the species are prevented from reacting with one another by the extremely low pressure in the outer jacket and plasma analyzer.

The apparatus also permits separation of reaction stages, such as flame stages during combustion. This is accomplished by controlling the temperature profile within the cylinder. Furthermore, because of the temperature profile control and the quickness with which the plasma enters the analyzer, the analyzation of the reaction sample is accomplished adiabatically.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be served by letters patent of the United States is:

1. Apparatus comprising:

a. an upright hollow cylinder having an electrically conductive coating thereon;

b. an outer jacket sealingly engaged about said cylinder;

c. a vacuum source connected to said jacket;

d. inlet means in the lower portion of said cylinder;

e. exhaust means in the upper portion of said cylinder;

f. lower heating means above said inlet means;

g. upper heating means below said exhaust means;

h. a sampling port in said cylinder between said upper and lower heating means, said port being about 25 microns in diameter and flush with the inner wall of said cylinder;

i. a plasma identifying means located within said jacket and adjacent to said sampling port at such distance that the traverse time of a plasma sample from said sampling port to said plasma identifying means is from about 3 to about 5 microseconds.

j. means to regulate said upper and lower heating means, so that a specific temperature profile is maintained in said cylinder.

2. An apparatus according to claim **1** wherein said electrically conductive coating is stannic oxide.

3. An apparatus according to claim **1** wherein said plasma identifying means is a spectrometer.

4. An apparatus according to claim **3** wherein said spectrometer is a mass spectrometer.

5. An apparatus according to claim **1** wherein said upper and lower heating means comprises silver print paint in conjunction with an electrical energy source.

6. An apparatus according to claim **1** wherein said sampling port is a cone-shaped opening.

7. An apparatus according to claim **1** wherein said exhaust means further includes a vacuum pump.

8. An apparatus according to claim **1** wherein said jacket contains a viewing port.

9. An apparatus according to claim **1** wherein said means to regulate the heating means includes temperature sensor probes extended axially within said cylinder at each end of said cylinder.

10. An apparatus according to claim **1** wherein a compressor is located at said inlet means.

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